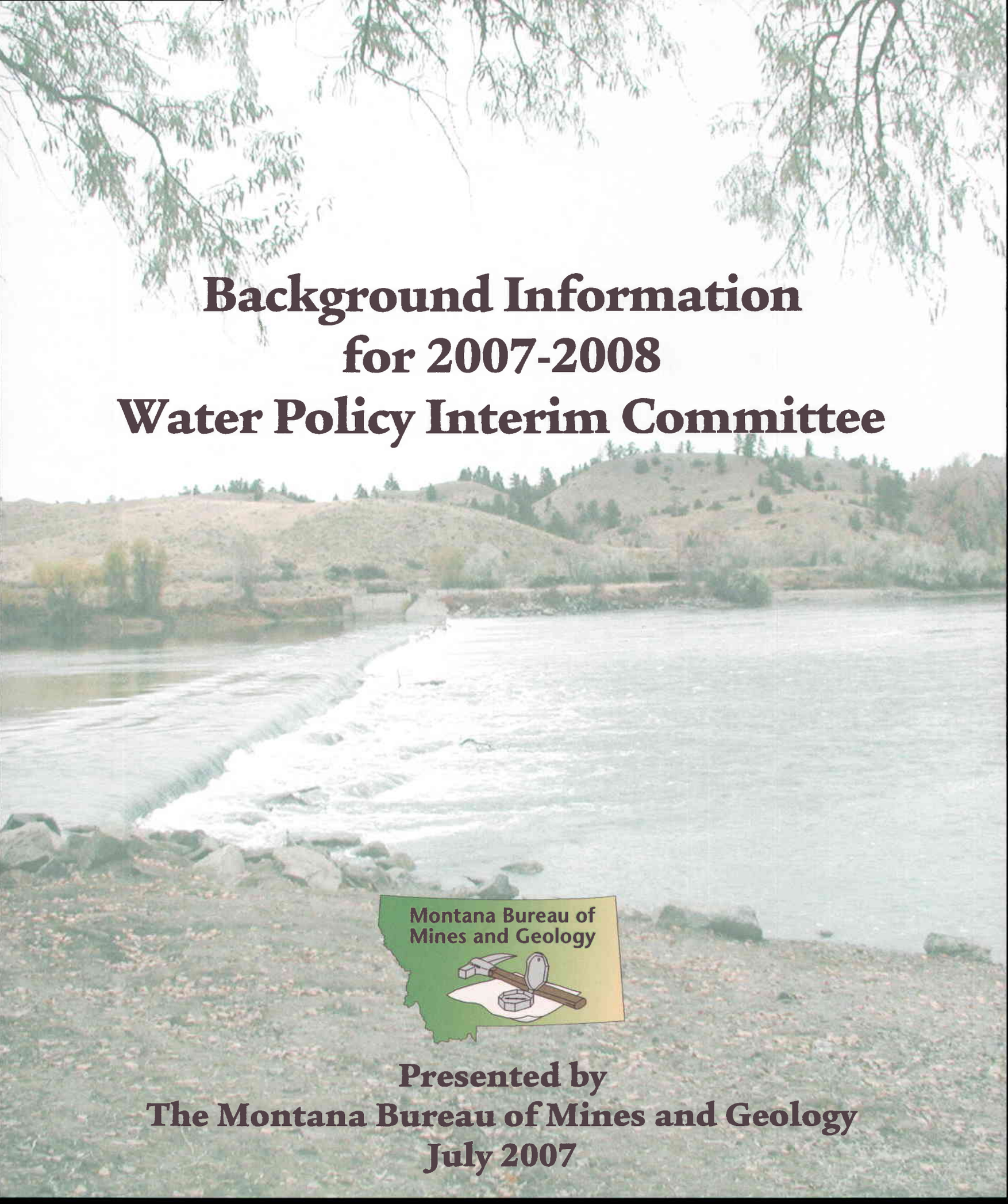
Background Information for 2007-2008 Water Policy Interim Committee



Montana Bureau of Mines and Geology

Presented by
The Montana Bureau of Mines and Geology
July 2007

FIELD TRIP

Legend

- well monitored for upper Beaverhead study MBMG OFR 834
- MBMG monitoring well
- irrigation well (from GWIC)
- water well (from GWIC)

0 5 Miles

Scale 1:100,000

MBMG

July 10, 2007

Legend

- well monitored for upper Beaverhead study MBMG OFR 834
- MBMG monitoring well
- irrigation well (from GWIC)
- water well (from GWIC)

2005 Color Infrared from NRIS

0 5 Miles

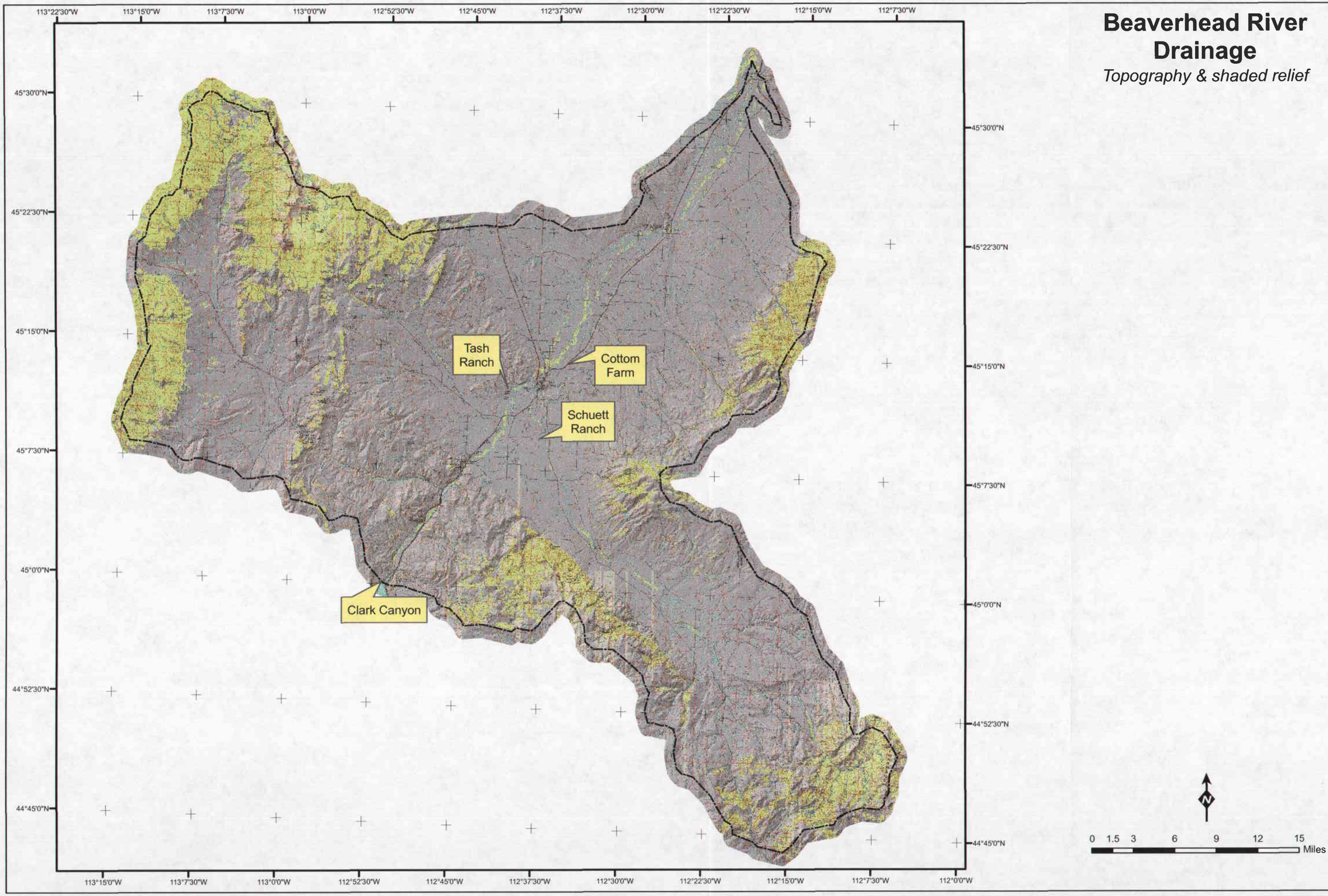
Scale 1:100,000

MBMG

July 10, 2007

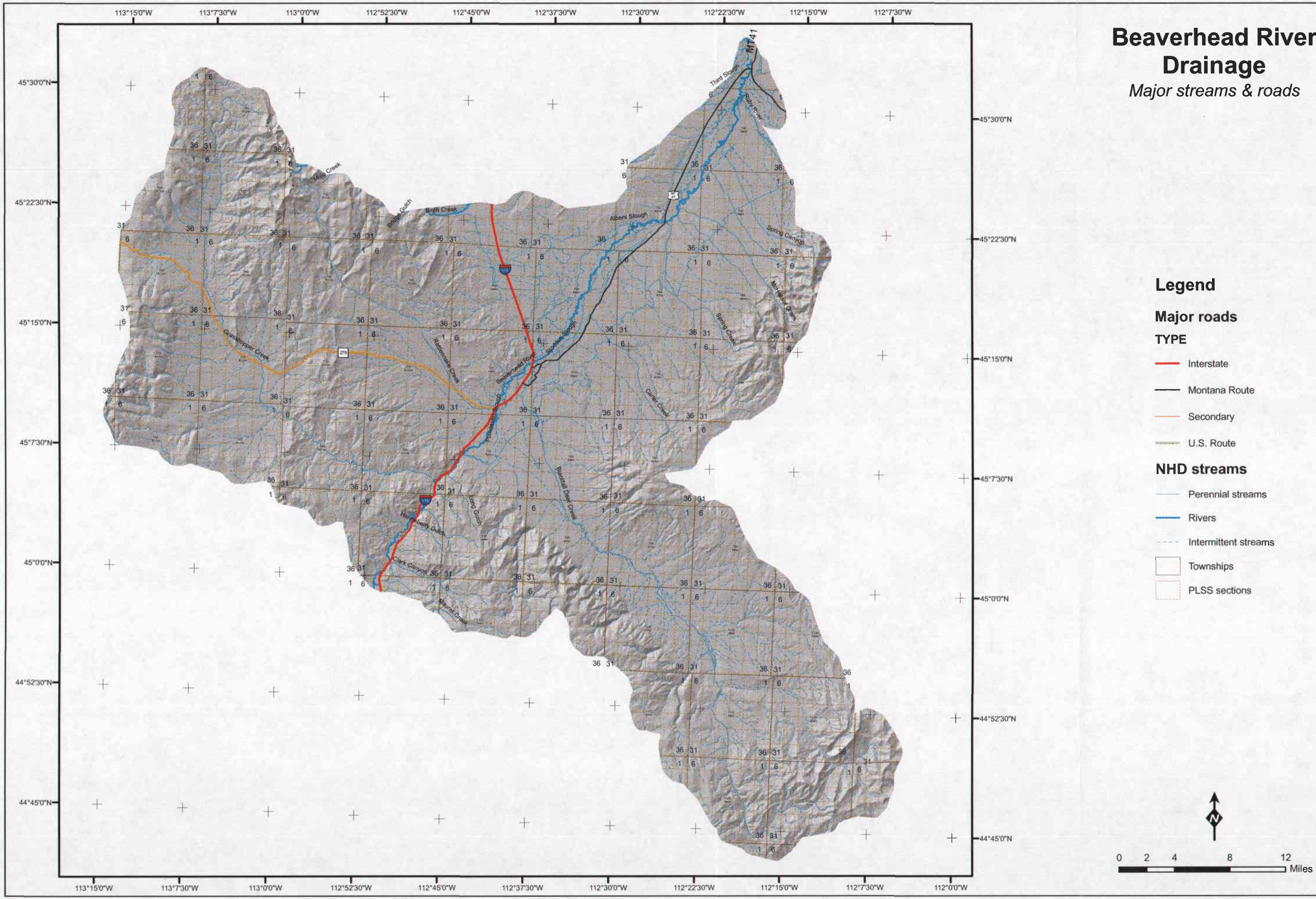
Beaverhead River Drainage

Topography & shaded relief



Beaverhead River Drainage

Major streams & roads



Legend

Major roads

TYPE

- Interstate
- Montana Route
- Secondary
- U.S. Route

NHD streams

- Perennial streams
- Rivers
- Intermittent streams

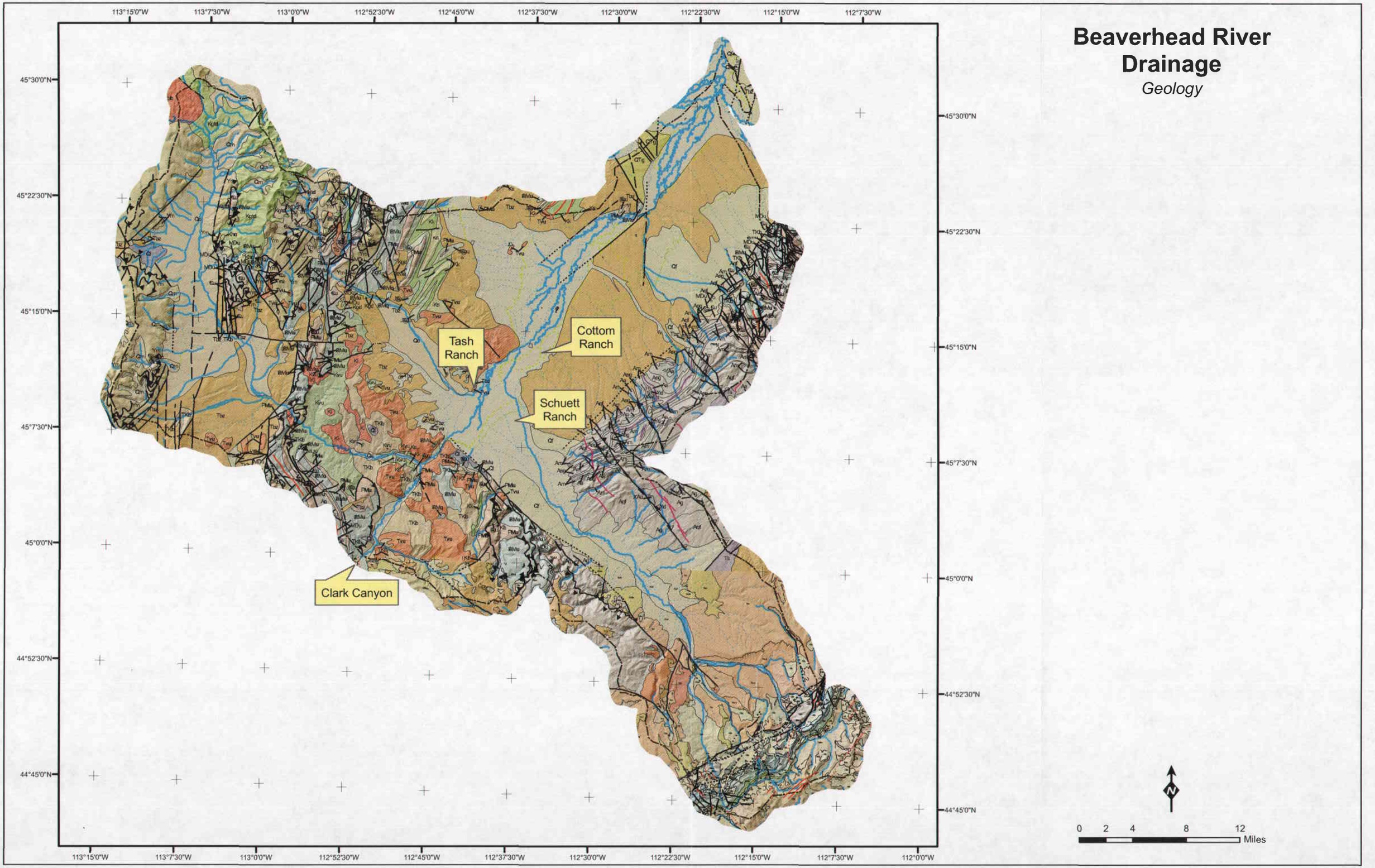
- Townships
- PLSS sections

N

0 2 4 8 12 Miles

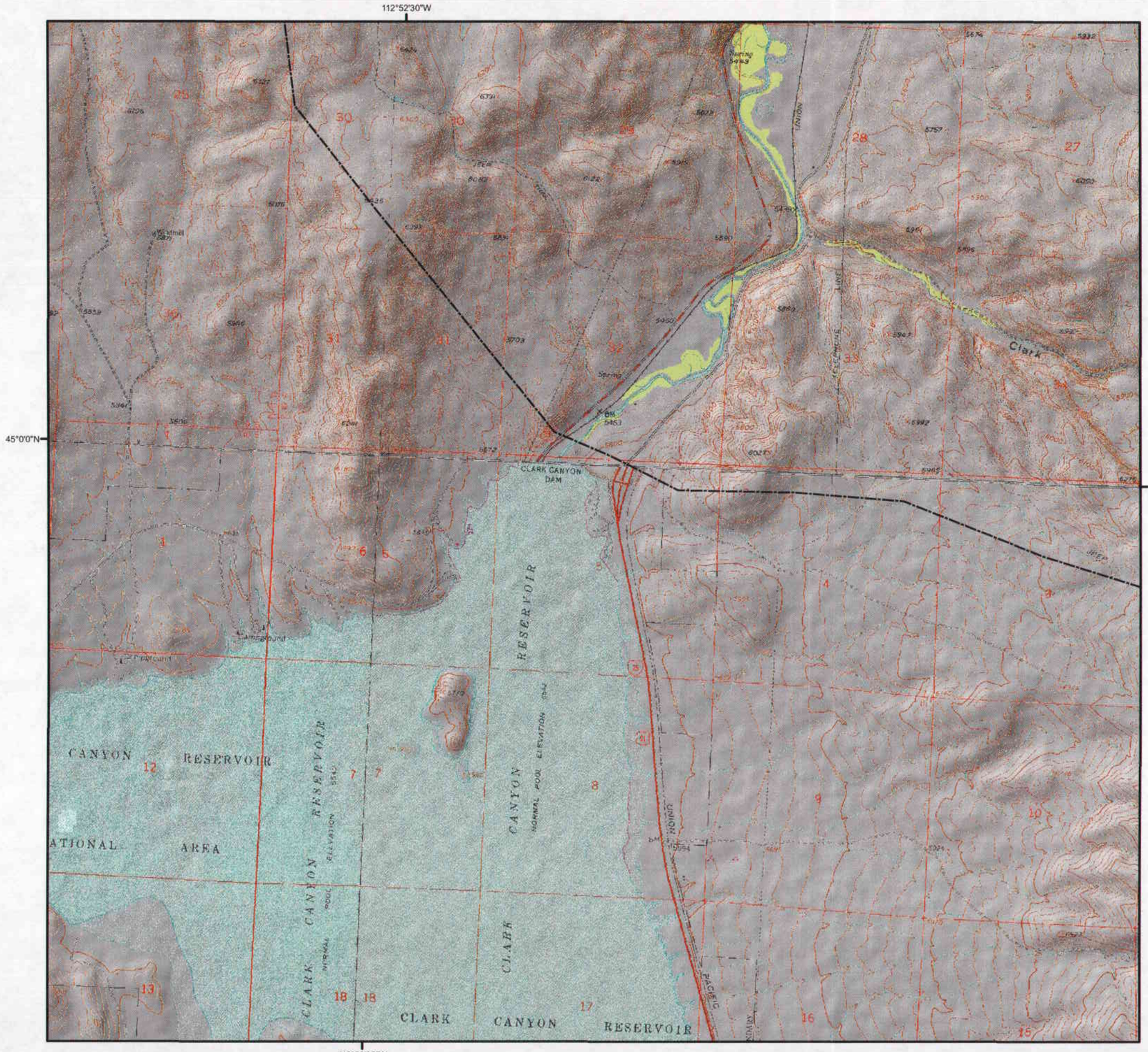
Beaverhead River Drainage

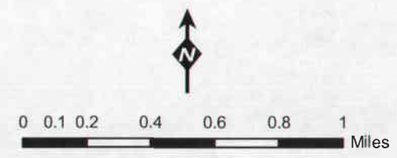
Geology



Beaverhead River Drainage

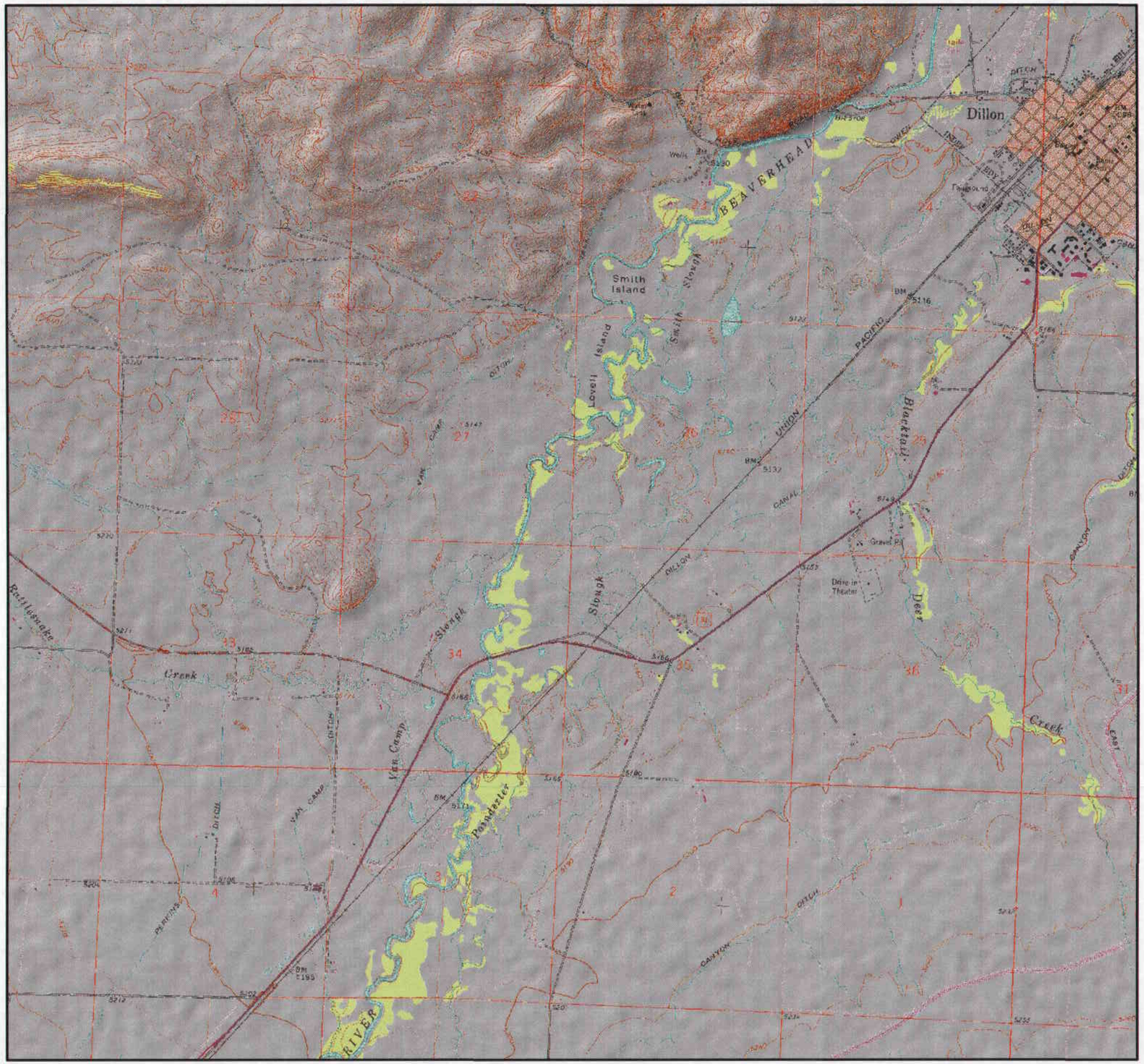
Clark Canyon Area

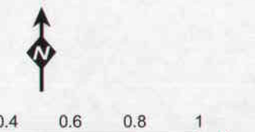




Beaverhead River Drainage

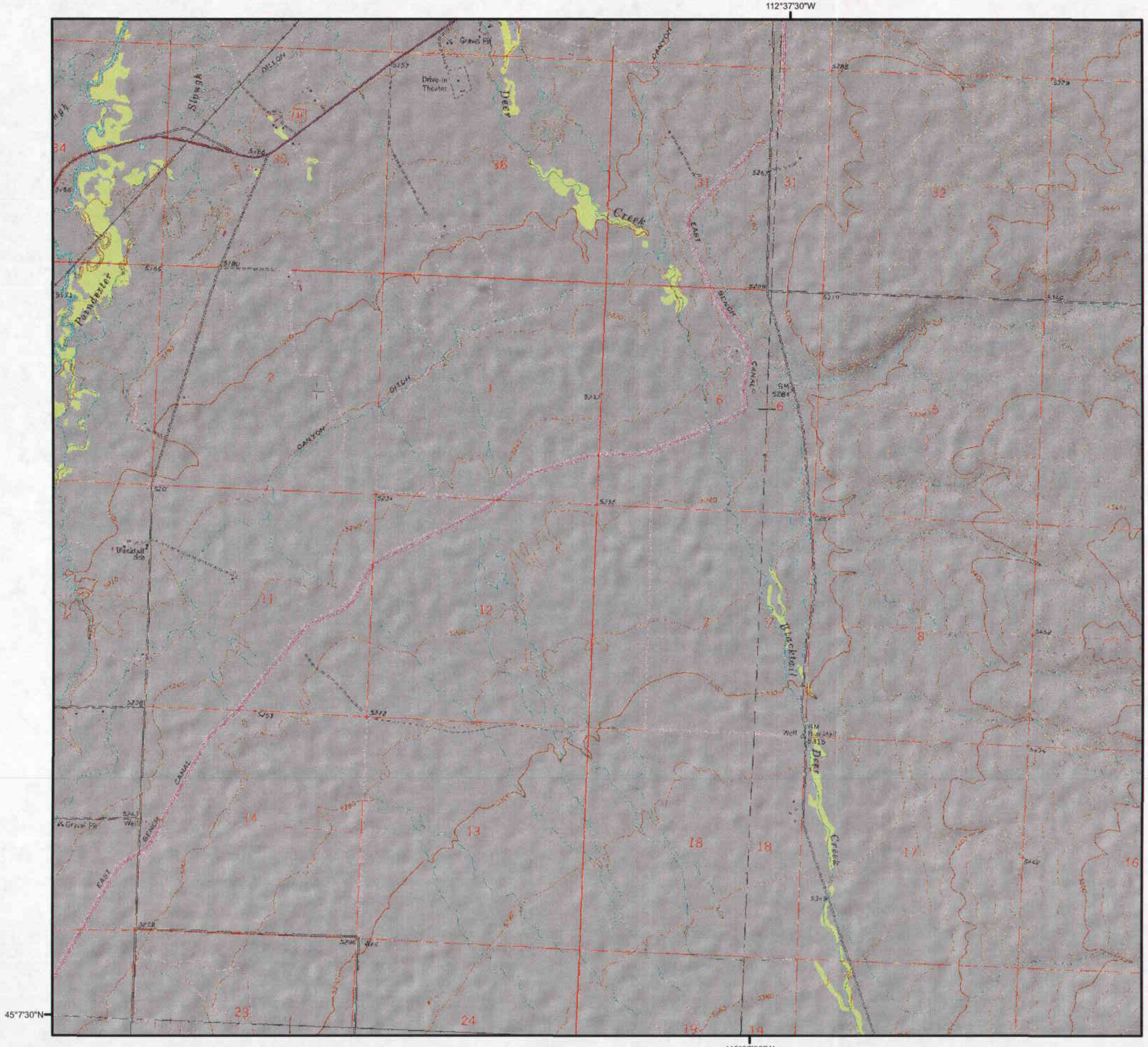
Tash Ranch stop

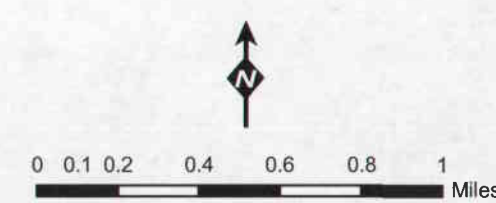


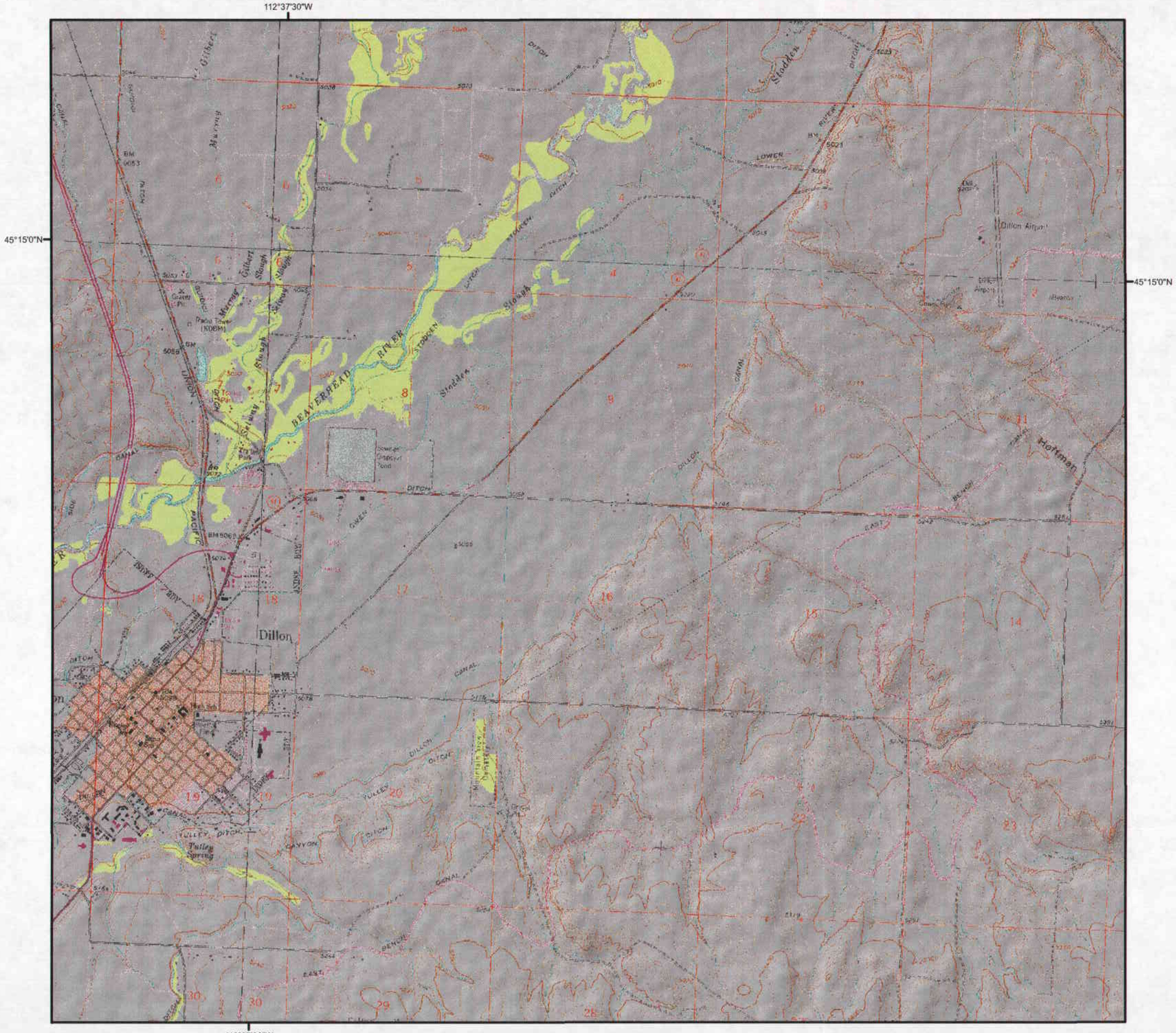


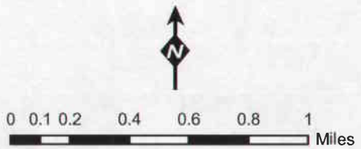
Beaverhead River Drainage

Schuett Ranch stop







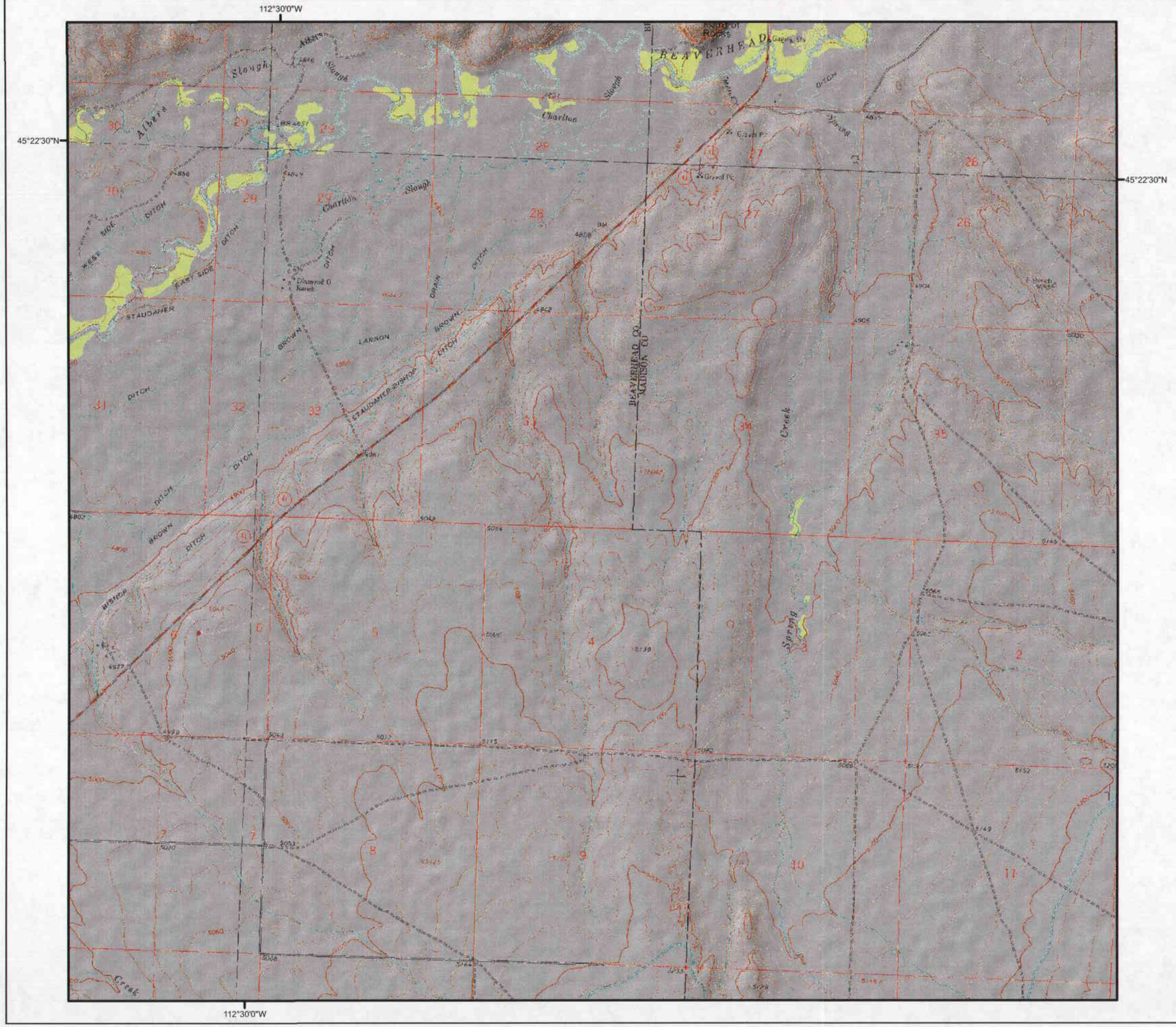


Beaverhead River Drainage

Cottom Farm stop

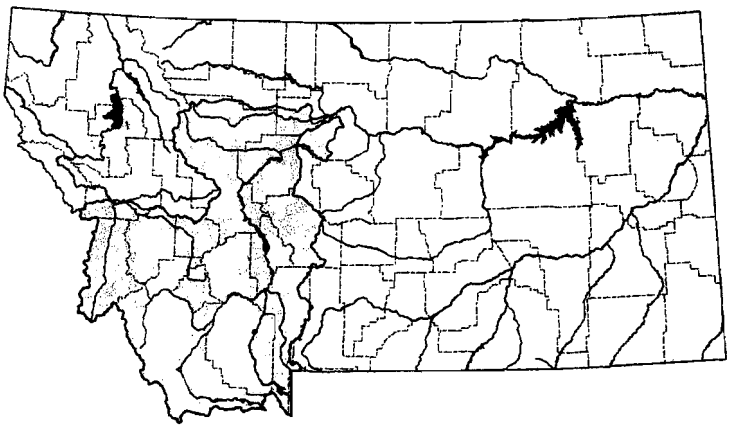
Beaverhead River Drainage

Mogus Ranch stop

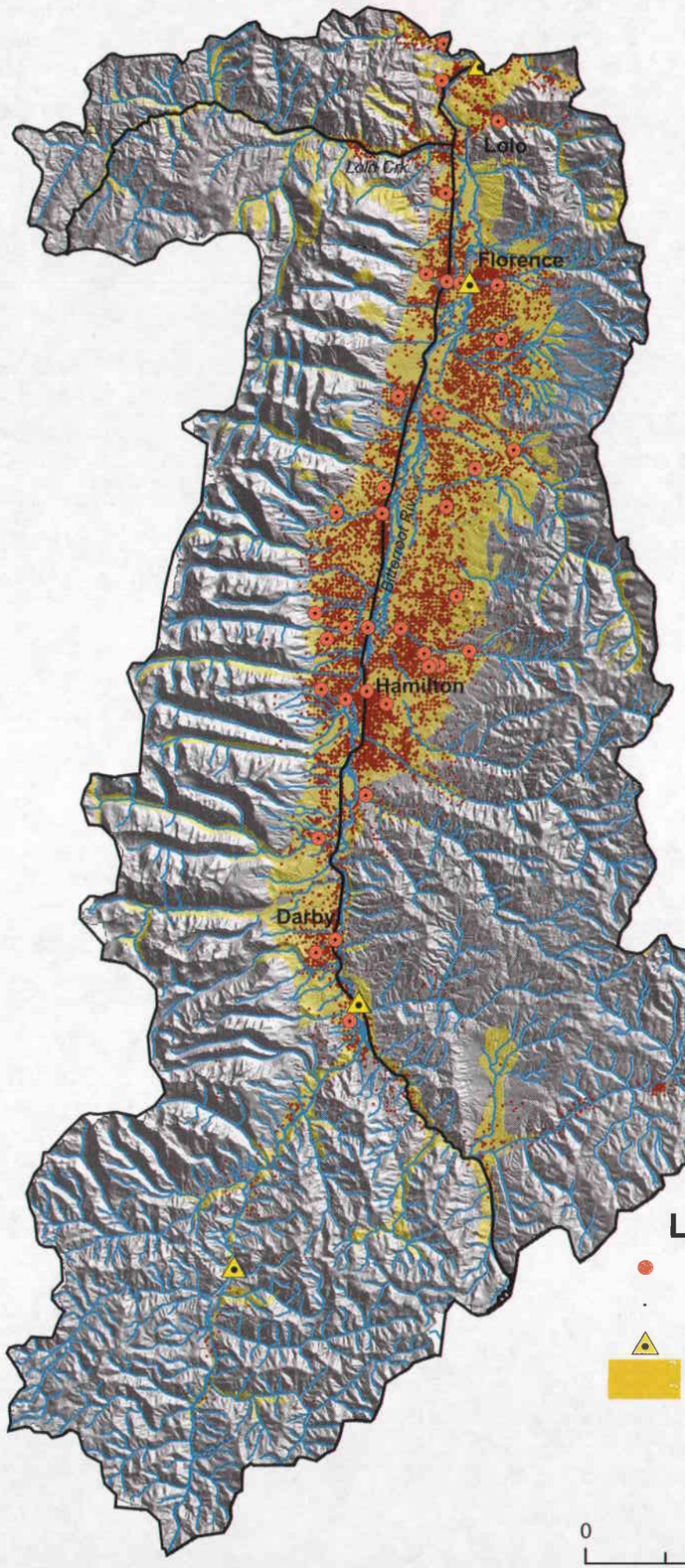


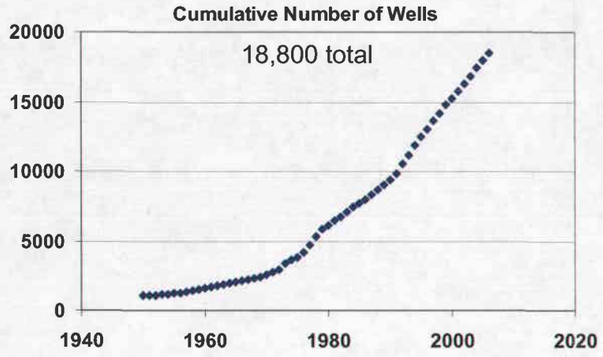
CLOSED BASINS

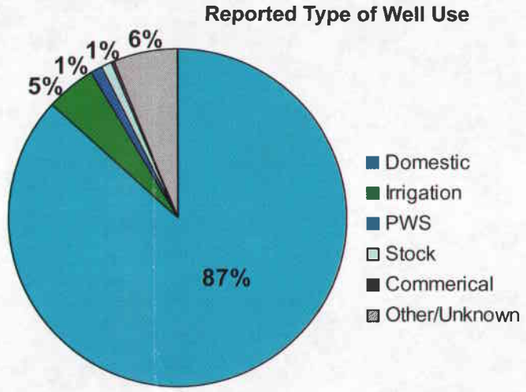
Bitterroot Basin

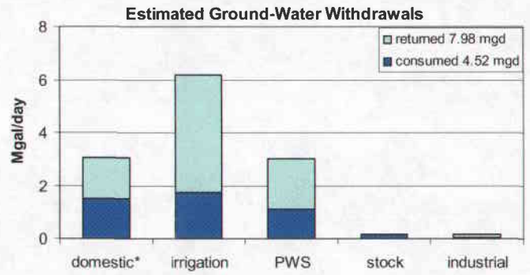


Bitterroot Basin Well Information









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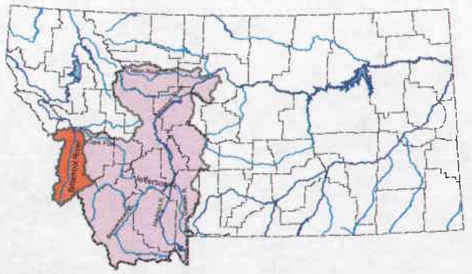
*Domestic consumptive use was assumed to be 50 percent of total withdrawals.
http://water.usgs.gov/watuse/pdf1995/pdf/domestic.pdf



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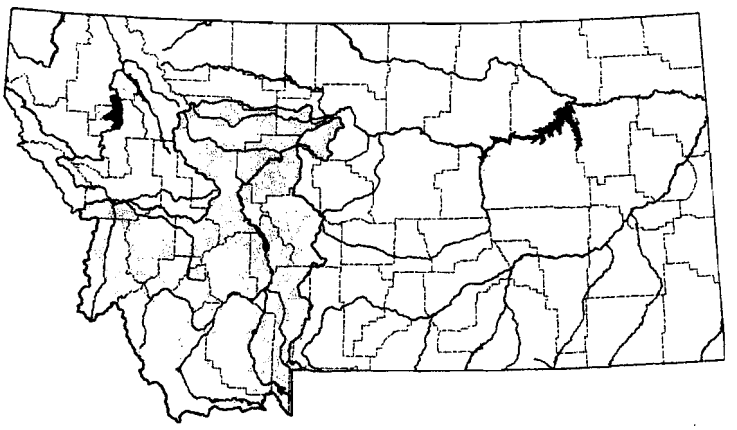
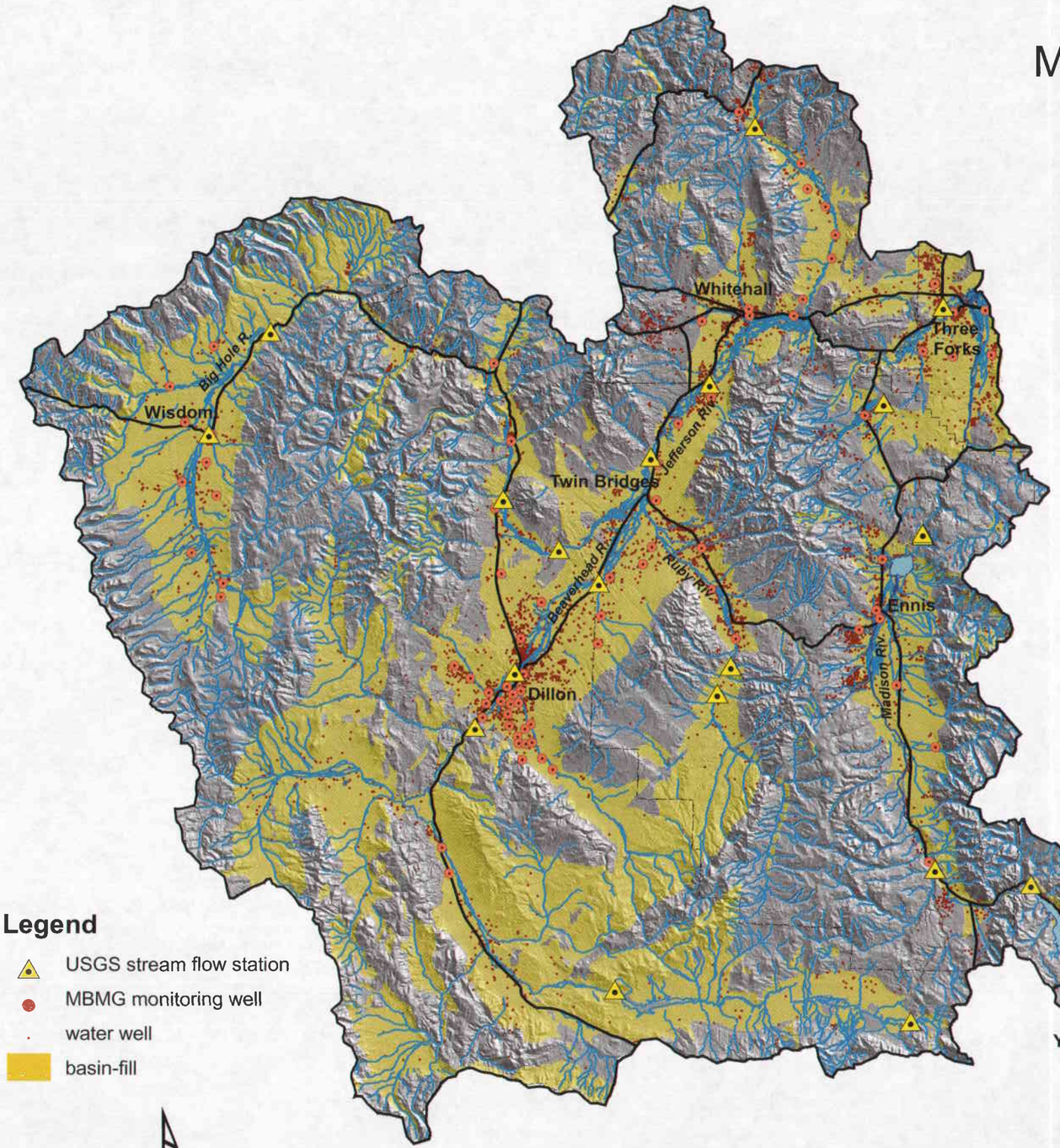
Madison & Jefferson Basins



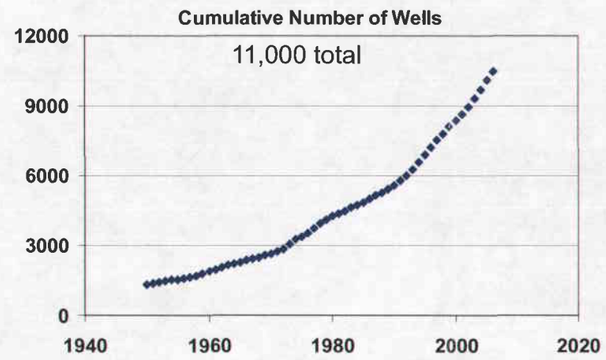
Madison and Jefferson Well Information

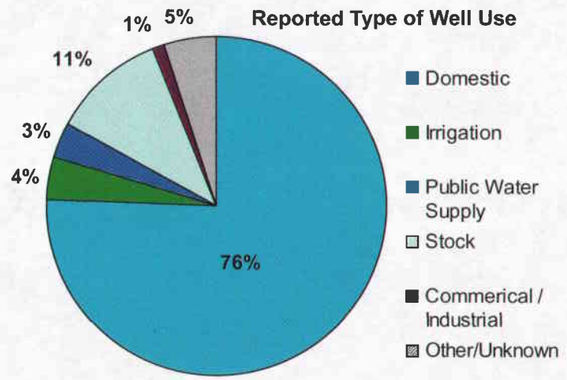


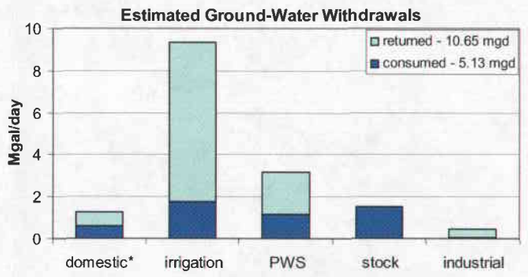
Legend

- USGS stream flow station
- MBMG monitoring well
- water well
- basin-fill

0 40 Miles







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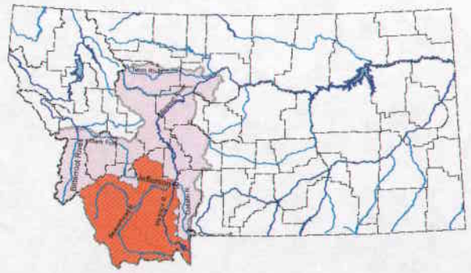

MBMG
July 10, 2007

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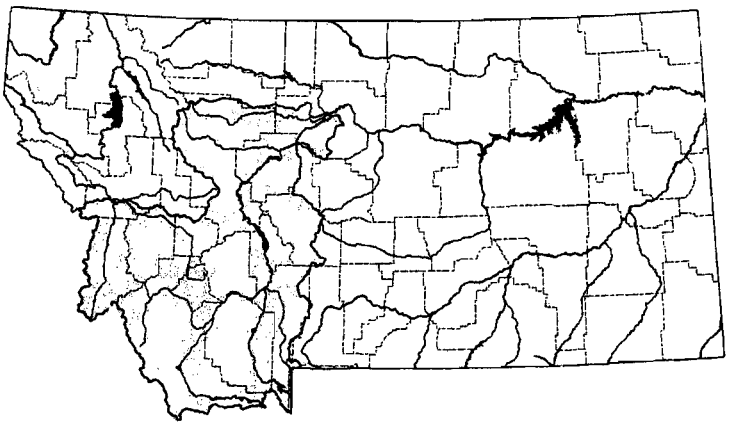

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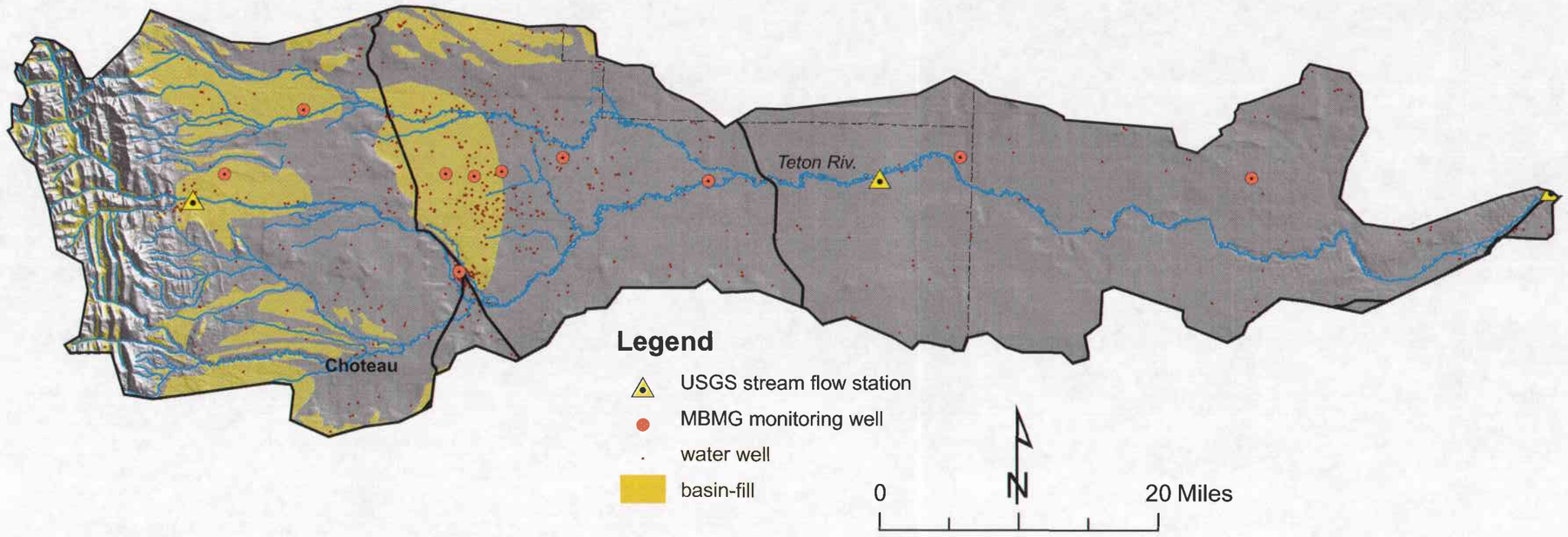

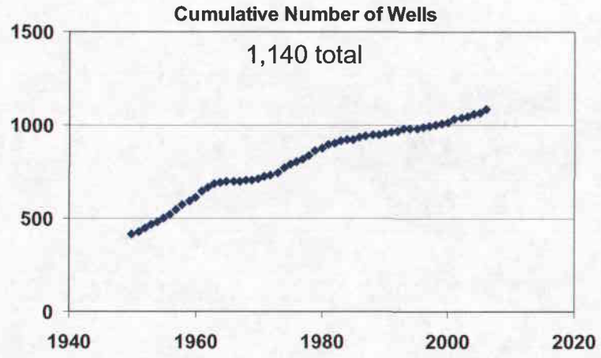

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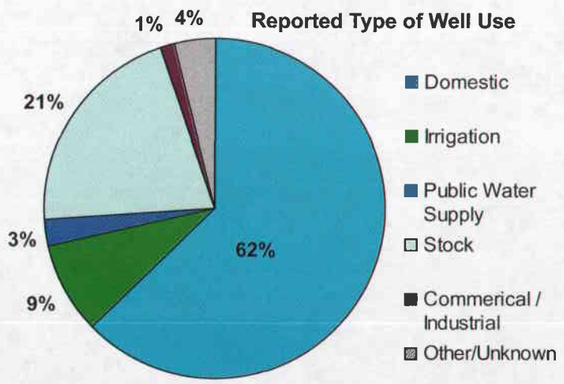

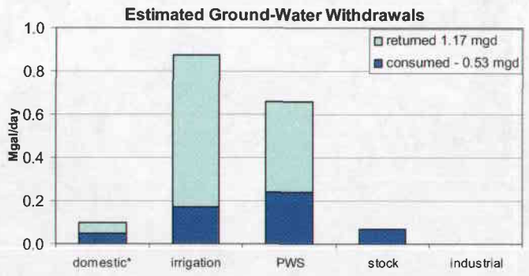

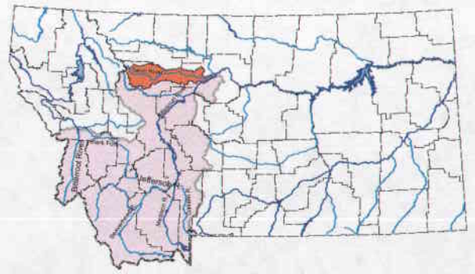

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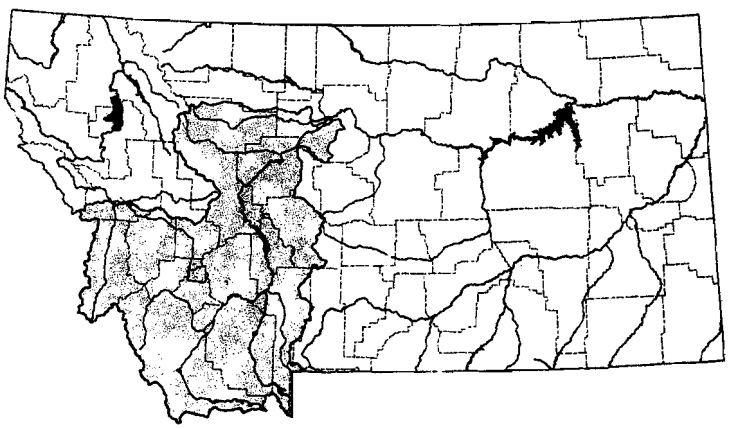

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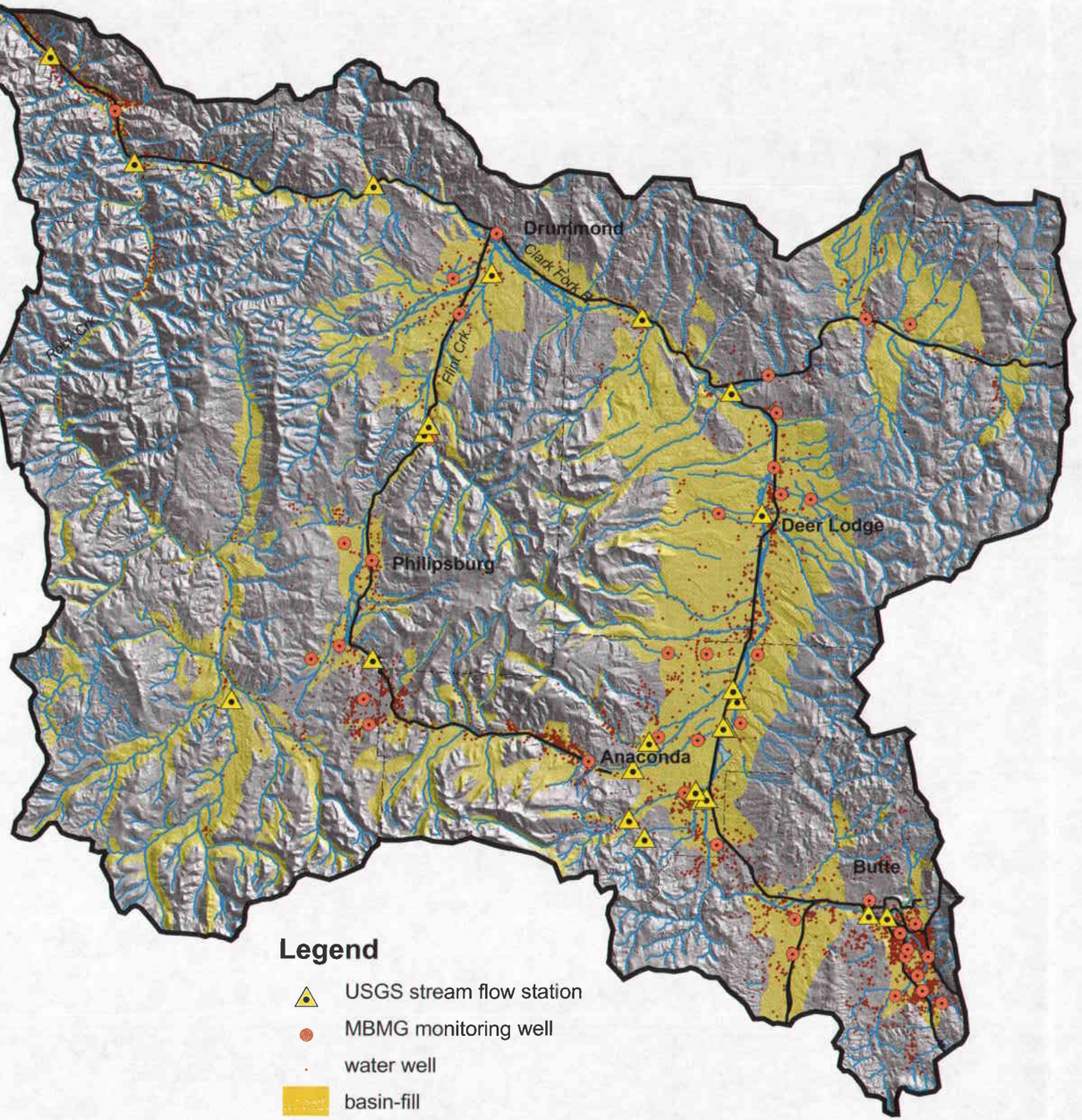

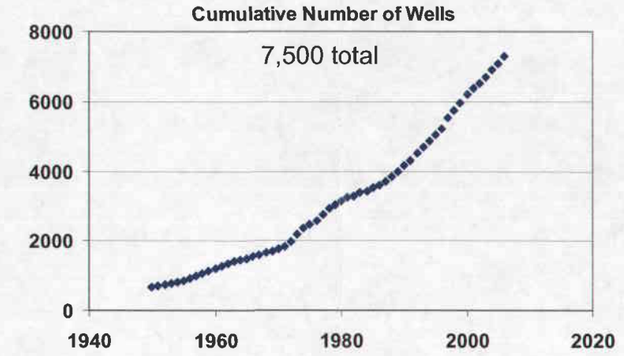

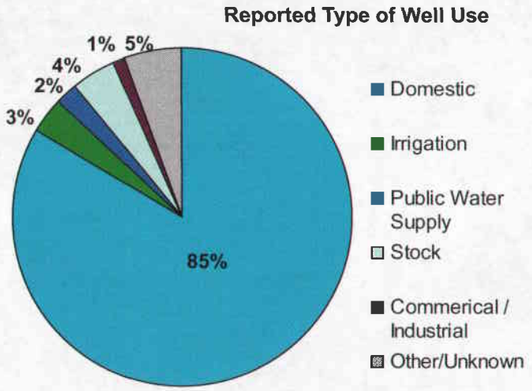

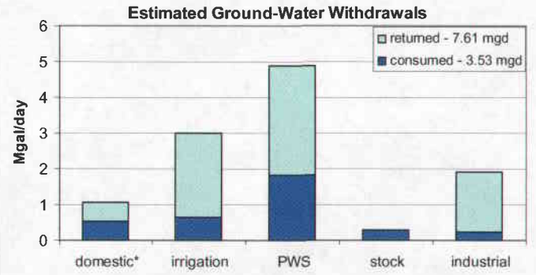

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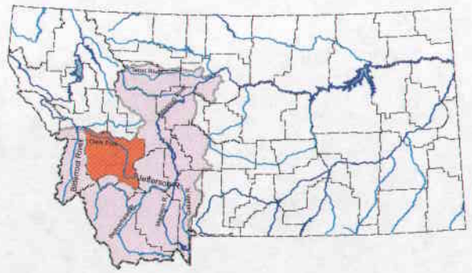

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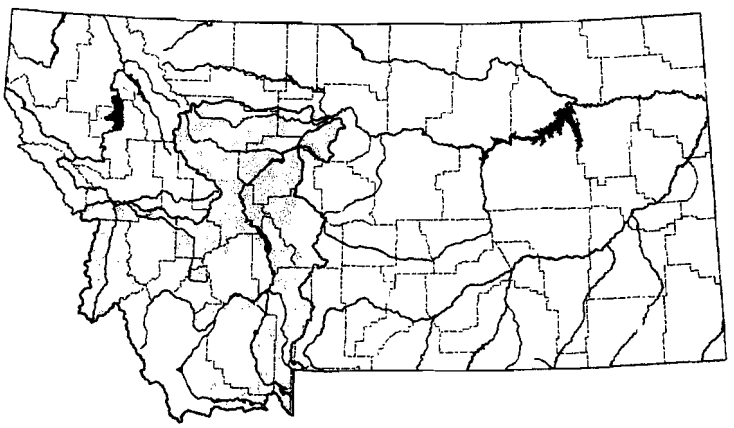
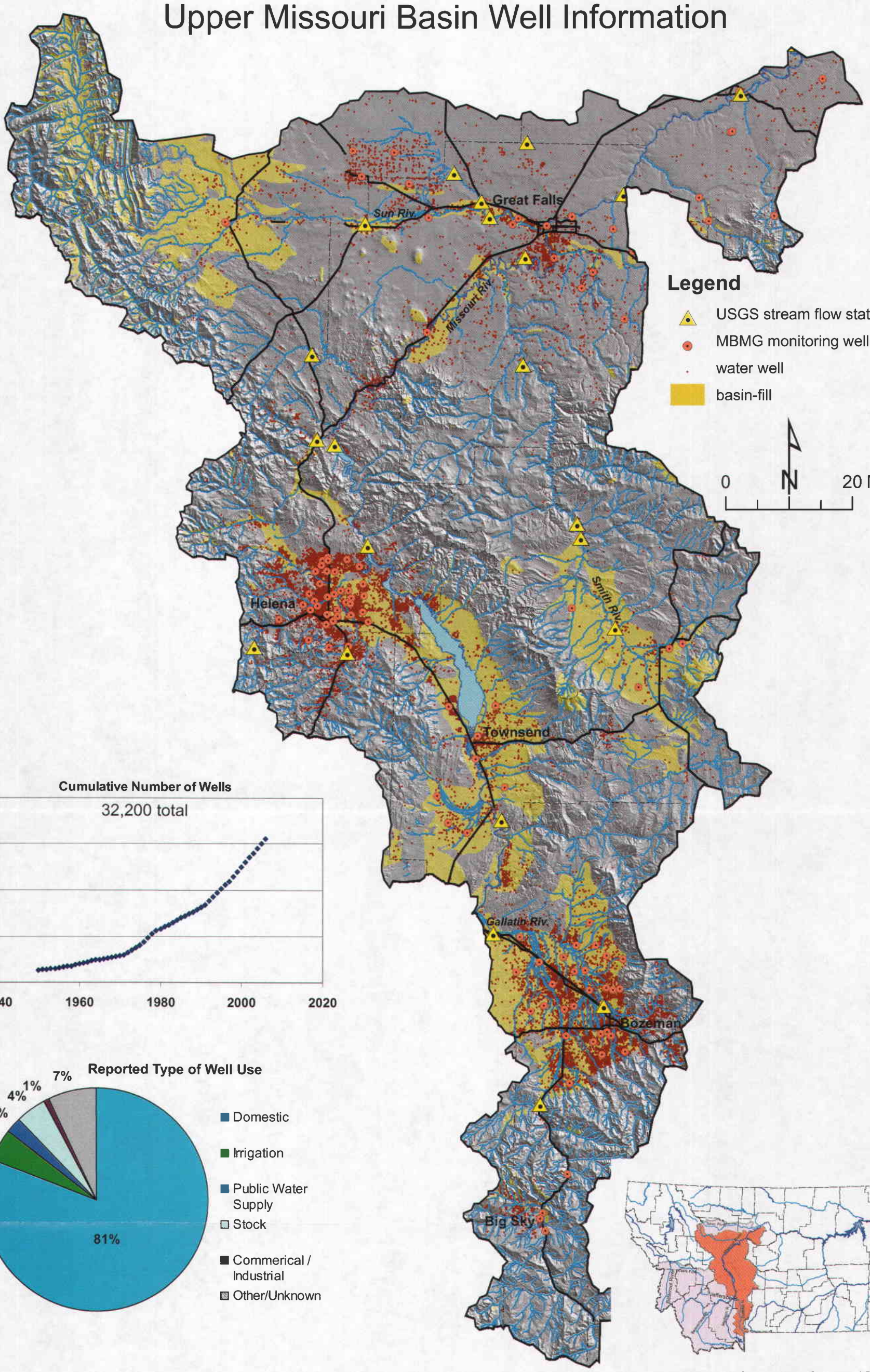
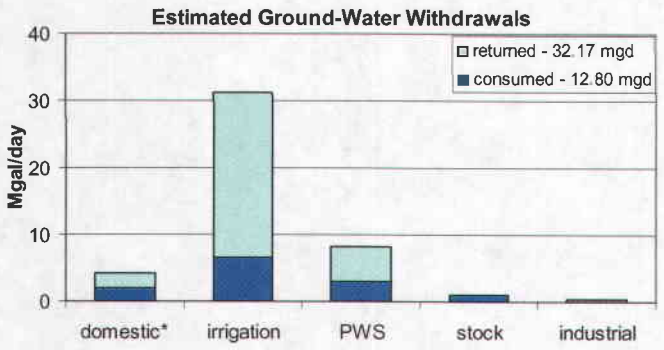


Upper Missouri Basin Well Information





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MBMG
July 10, 2007

Upper Missouri Basin

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WORK PLAN

Montana Bureau of Mines and Geology
WORK PLAN

PART A: Review of closed basins

Closed basin case study (Section 23)
(1a) the Montana Bureau of Mines and Geology, provided for in 20-25-211, shall review, assess for scientific accuracy, and compile ground water studies that have been conducted in the last 20 years in closed basins or subbasins in Montana that may have a bearing on better understanding the water balance in these basins with respect to potential ground water withdrawal impacts on surface water.

(1b) after compilation of the information, the Bureau of Mines and Geology shall present recommendations to the appropriate legislative interim committee regarding any additional studies that would help to assess the water balance in closed basins or subbasins with respect to potential ground water withdrawal impacts on surface waters.

The MBMG has initiated compilation, review, and assessment of studies related to ground water within the closed basins. These reports will be compiled in electronic bibliographic format and provided to the WPIC. The MBMG will use these references and other information to make recommendations as to additional studies related to water balance and potential impacts of ground-water withdrawals on surface water within the closed basins. The MBMG's initial recommendations are provided in PART B of this work plan.

PART B: Case Study

Section 23
(2) The Bureau of Mines and Geology shall conduct a case study to gather and develop data to determine the adequacy of any additional recommended minimum standards and criteria for hydrogeologic assessments, as defined in section 15, associated with ground water withdrawals and the range of impacts of those withdrawals on surface water and ground water resources. The Department of Natural Resources and Conservation shall coordinate with the Bureau of Mines and Geology with regard to surface water monitoring and other elements of the case study as necessary.

(3) The case study must be conducted in basins closed pursuant to sections 85-2-330, 85-2-336, 85-2-341, 85-2-343, or 85-2-344. The bureau of mines and geology shall ensure that at each site involved in the case study the following, at a minimum, is accomplished to provide the necessary scientific data and information to policymakers:
(a) an appropriate number of monitoring wells are drilled or available to provide scientifically defensible data;
(b) aquifer testing and recovery testing is conducted at the site;
(c) water quality samples are collected from each pumping or primary well at the beginning of the case study and a the end of the case study;
(d) if information or data has already been collected for the site, the information is reviewed, analyzed, and verified by the bureau of mines and geology;
(e) if the site has an established system, that the established system is monitored under its current or planned operating conditions; and
(f) any other information is collected that the bureau of mines and geology determines is necessary to make recommendations for additional minimum standards and criteria for hydrogeologic assessments, as defined in section 15, associated with ground water withdrawals and the range of impacts those withdrawals have on surface water and ground water resources.

(4) In addition to the requirements of subsection (3), the bureau of mines and geology shall develop a system to compile existing aquifer testing data, as well as data resulting from hydrogeologic assessments, as defined in section 15, and monitoring activities.

The Case Study will comprise three phases: 1) site investigations, 2) site-scale and basin-scale assessments of impacts, and 3) evaluation/development of criteria for hydrologic assessments for permit applications.

1) Site Investigations: Past or pending permit applications in closed basins will be evaluated with respect to the various hydrogeologic conditions that occur in closed basins, including:

a) near stream shallow alluvial aquifers;
b) deep basin, confined or semi confined aquifers;
c) intrabasin or interbasin aquifers below the basin-fill aquifers; and
d) basin margin / bedrock (fault controlled).

The objective of these investigations will be to 1) describe these hydrologic settings particularly where ground water is likely to be developed, 2) describe the range of potential impacts to ground water and surface water under each setting, and 3) assess the adequacy of the current methods used to predict stream depletion within the range of hydrogeologic conditions present in the closed basins.

Each site investigation will include a review of existing reports, data (lithology from well logs, aquifer test data, geology, chemistry), and analyses; the review will determine the need, if any, for additional data including aquifer tests, additional monitoring wells, additional water quality sampling, and additional analyses of pumping effects with distance and time. The MBMG will then conduct field work to gather data and perform analyses using the additional information.

Sites presently under consideration for the site investigations are briefly summarized in Appendix 1. In accordance with Section 23 (4), aquifer test and monitoring data compiled for each site investigation, along with additional data collected by the MBMG will be available through the Ground-Water Information Center database. The MBMG has initiated a system to accept aquifer test data and hydrologic assessments for electronic storage and retrieval.

2) Site-scale and Basin-scale Assessments: The results of the site investigations will be used to construct generic conceptual and computer-based models of the range of hydrologic conditions evaluated in the site investigations. In addition to pumping, each hydrologic condition, or combination of hydrologic conditions, will be modeled to examine the effects of such variable stresses as recharge (natural and artificial), evapotranspiration (seasonal and land use change), cumulative pumping (irrigation and domestic).

The approach will be to construct a matrix of hydrologic conditions versus stress based on aquifer characteristics and dimensions found in southwest Montana. Initially, each hydrologic condition will be modeled under background conditions (figure 1). Then, for each hydrologic condition, new stresses (pumping) will be added; the impact to ground-water levels, surface-water flow, water levels in other wells will be examined (figure 2). For example, shallow, near stream conditions will be modeled initially under background or existing conditions (no pumping occurs at the site, but may occur nearby for pre-existing irrigation wells); then a new stress, pumping with a single irrigation well will be examined at various distances and pumping rates over an appropriate period of time.

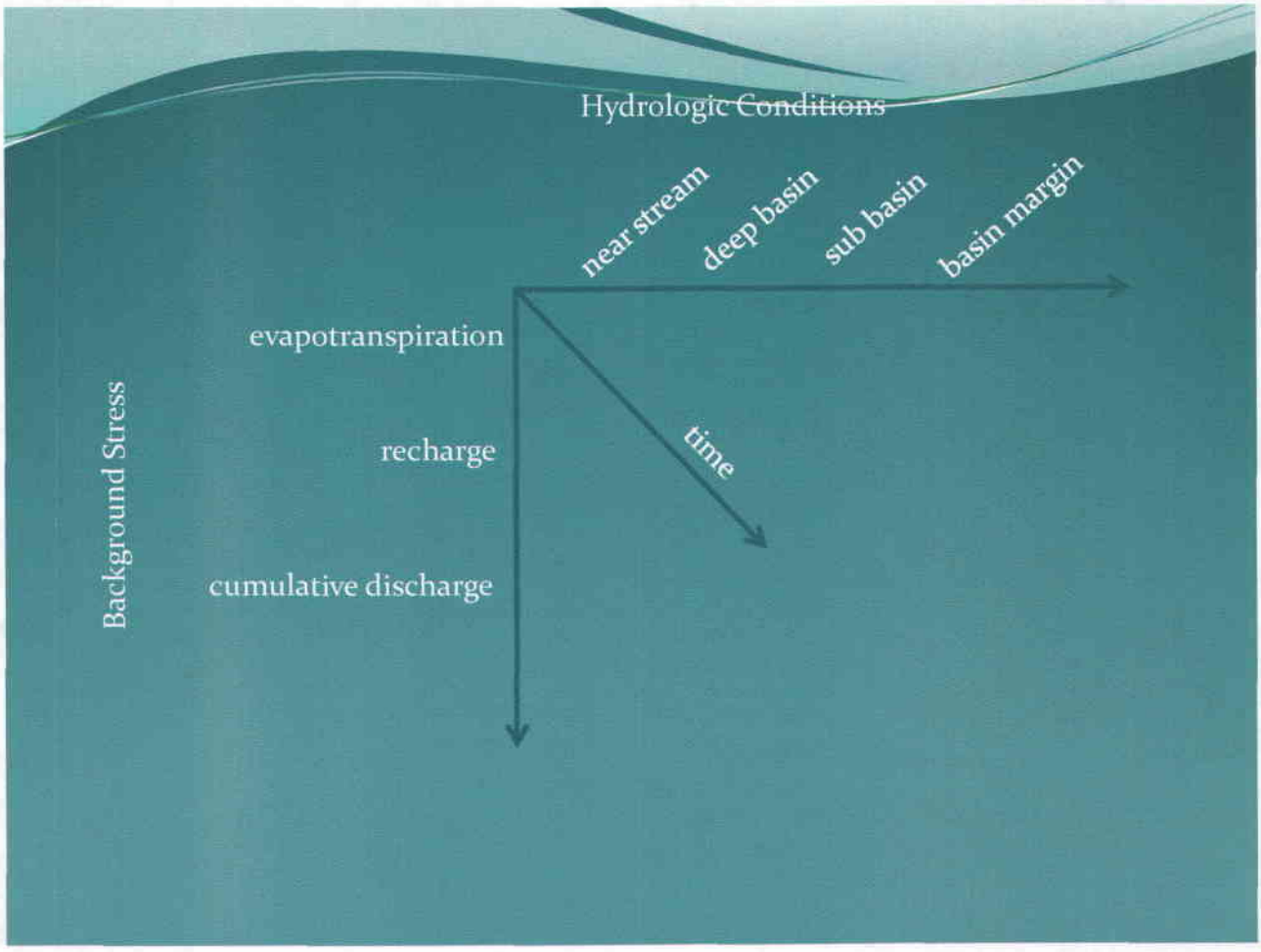


Figure 1. The primary matrix for the case study examines each hydrologic condition under baseline or background stress conditions.

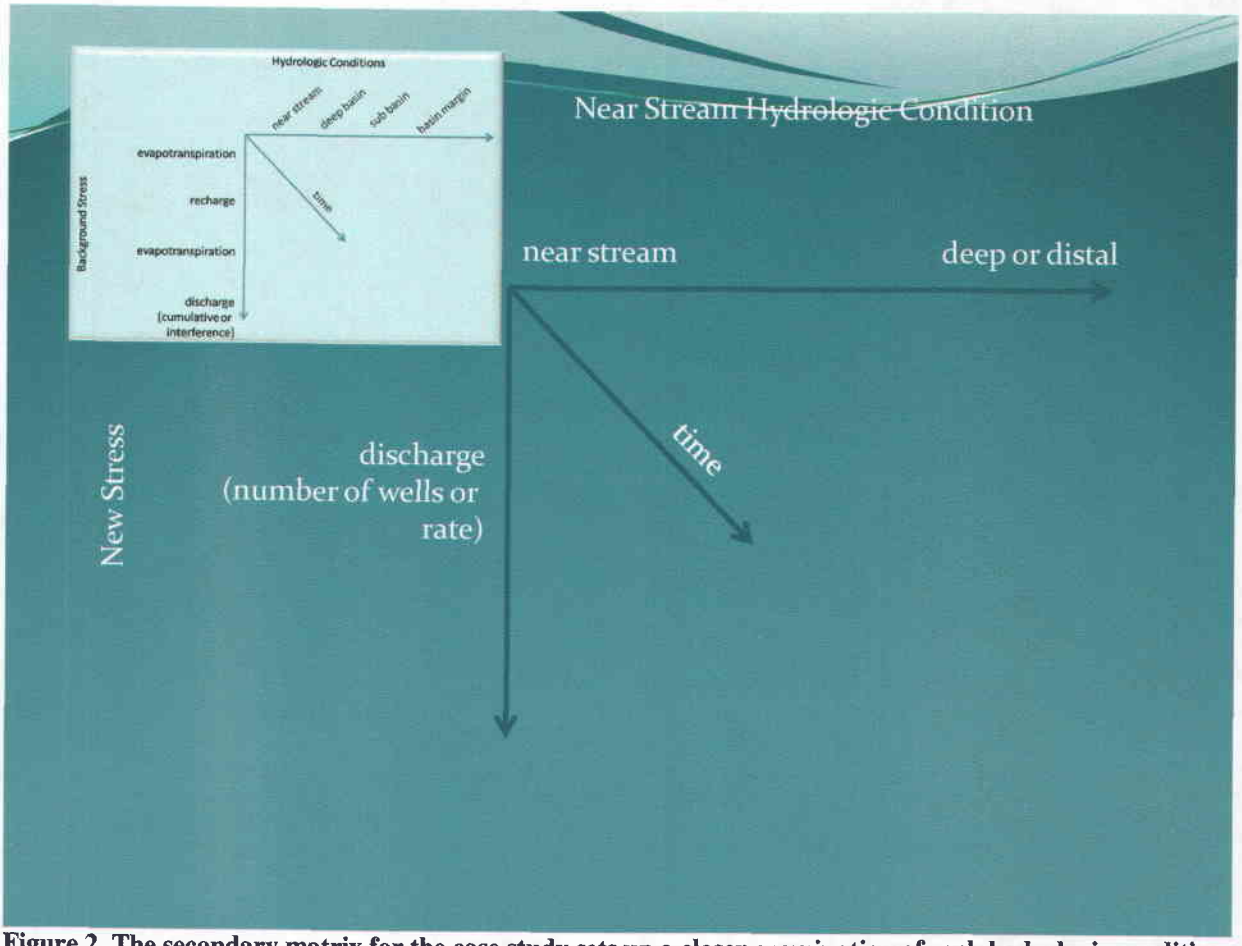


Figure 2 The secondary matrix for the case study sets up a closer examination of each hydrologic condition established in the primary matrix.

The overall process is illustrated by example:

- A review of about 20 outstanding applications shows that there are several permit applications for wells installed within the shallow near-stream aquifer. The hydrologic assessment reports will be examined for their value in the overall analysis and their appropriateness for that application. *The goal is not to evaluate an individual application, but to find sites that represent the range of conditions found in the closed basins.*
- At least one, but likely several sites will be selected for a detailed examination of the hydrologic condition with particular attention paid to the aquifer test (duration, type of analyses, etc.), monitoring well placement (distance from pumped well and stream, depth, etc.), and stream characteristics (total flow, gain/loss characteristics, etc.). The detailed examination will determine if additional data (more monitoring wells, more testing, water quality, etc.) are needed.

- If more data are desired for that site, the MBMG will seek cooperation and access from the applicant and their agents (if applicable) to conduct the field work.
- After completion of the field work, all data for each will be compiled and used to evaluate the potential impact of pumping on surface-water flow.
- A ground-water flow model will be constructed for one or more of the sites; this model will be site specific and will be calibrated using the pumping test data.
- A generic model of pumping from near-stream shallow aquifer at various discharge rates, under various background/baseline conditions as shown in established in the primary matrix. The model will be then be used to describe the range of responses in ground water and surface water from pumping from wells at various positions in the aquifer at various depths and distances as established in the secondary matrix.

Evaluation of cumulative impacts will include those that occur locally (e.g. multiple wells with overlapping zones of influence) and area wide (multiple wells and/or multiple depths). The results of each the analyses generated by the matrices will be presented as summary for each hydrologic condition. A common tool for presentation will likely be a graph of ground-water decline over time compared to stream flow.

Each of the hydrologic conditions under background and new stresses will be modeled with a mitigation or management scheme defined in the matrix of figure 3. To continue with the example, after modeling near-stream shallow aquifers with various pumping rates and locations, the effect of mitigation by return flow, artificial recharge, and land use change will be evaluated. Output from this modeling will present a comparison of the effects of each mitigation/management option on the effects of pumping.

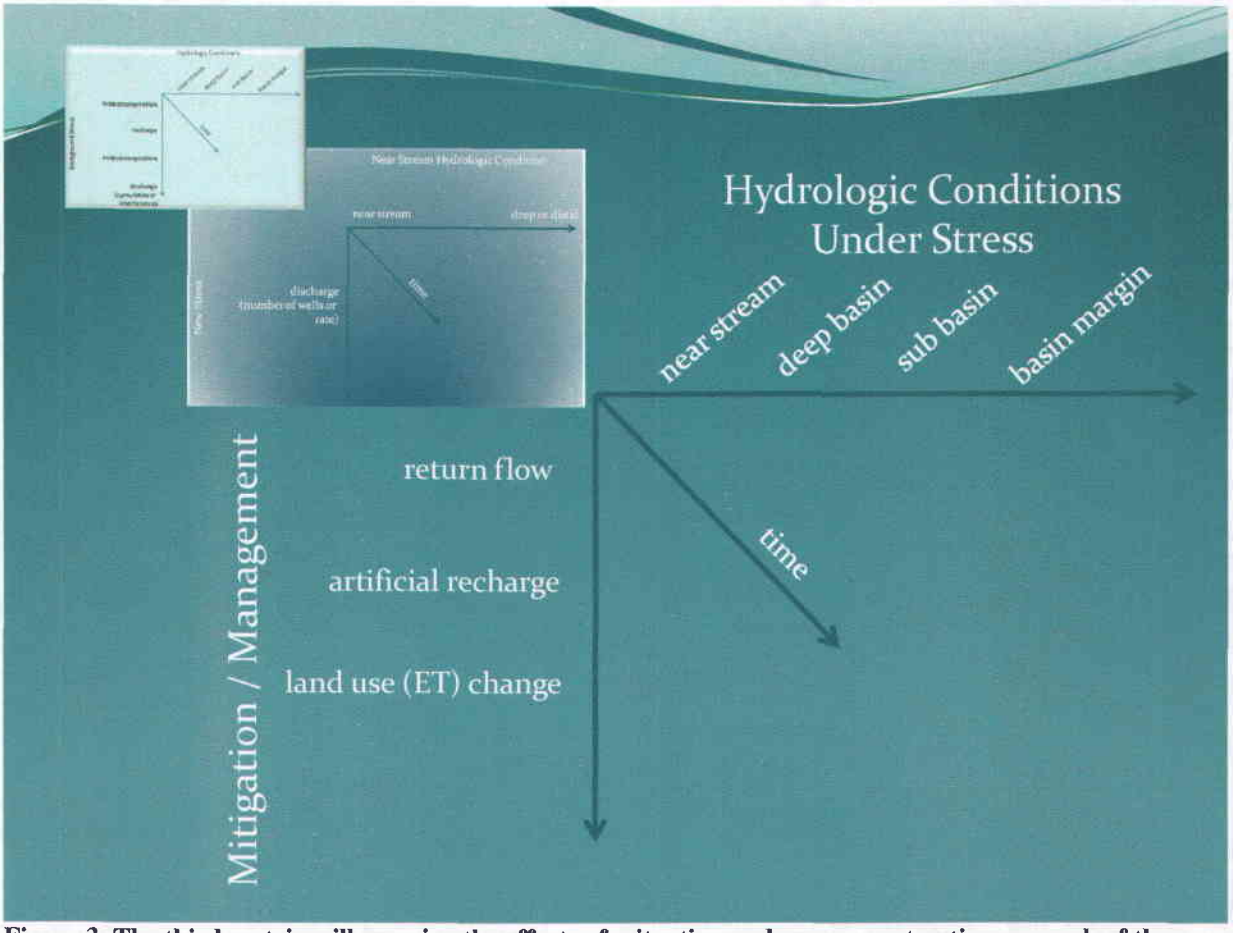


Figure 3 The third matrix will examine the effects of mitgation and managment options on each of the hydrologic conditions.

The modeling will be constrained by the range of aquifer parameters (transmissivity, storage coefficient, aquifer thickness / extent, etc.) the range of pre-existing stresses (existing pumping rates, recharge rates, ET values, etc.) that were determined in the site investigations. Sensitivity analyses will be used to describe the effects of the uncertainty related to the measurement of transmissivity, stream flow, water levels, etc.

3) Evaluation/development of Criteria: The site investigations and the modeling will be used to evaluate the adequacy of the existing hydrologic assessments and minimum standards. The MBMG will review the current permit process with respect to the data collected, the evaluation methods used, and make recommendations as to additional information and analyses as called for in Section 23(2) of HB831. These recommendations will relate to both individual permit applications and basin-scale evaluations.

Section 24. Case study -- requirements for participation (2) The bureau of mines and geology, in cooperation with the appropriate legislative interim committee, shall notify each of the entities described in subsection (1)(d), in writing, of the opportunity to participate in the case study and the requirements for participation.

Upon approval of this Work Plan by the WPIC, the MBMG will finalize its selection of sites for investigations and seek cooperation from individual well owners.

PART C: Committee Activities

The MBMG will participate in activities related to the Water Policy Interim Committee (WPIC) as requested and include:

1) Updates of MBMG activities to the committee at each meeting which include:
   a) progress report on HB831 Case Study
   b) status and current activities of the MBMG Ground Water Assessment Program
   c) progress report on 23(4): compiling existing aquifer testing data, as well as data resulting from hydrogeologic assessments for the Ground Water Information Center database.

2) the MBMG will provide presentations of background information related to hydrogeology that may include water balance calculations, the hydrologic cycle, ground-water flow modeling, geochemistry / geochemical modeling, aquifer testing / aquifer characteristics, and recharge as requested by the WPIC.

Appendix 1
Case Study Investigation Sites

Site Name (drainage): 1: 6S7W5(2), 5S7W32,6S7W6 (Beaverhead)

Status: permit application in progress

Potential hydrologic condition(s):

- near stream development
- recharge from ditch
- well interference
- deep and shallow production

Available data:

- production wells (several)
- stream flow staff gage
- monitoring wells on site
- monitoring wells off site

Notes:
3 wells in permit process. Total depths range from 160 to 520 fbgs, multiple screen intervals
aquifer tests on each (~70 hours)

may also want to include nearby properties - same drainage, similar range of conditions

****

Site Name (drainage): 2: 2N2E35 (Gallatin)
near Logan/Manhattan/Amsterdam

Status: permit application in progress

Potential hydrologic condition(s):

deep / sub basin
Tertiary sediments
other wells in area are completed in the Madison LS

Available data:
production well
monitoring wells on site (72 hour pumping test)

Notes:
other permit applications in the same area, same aquifer

****
Site Name (drainage): 3: 5S8W32 (Beaverhead)

Status: permit application in progress

Potential hydrologic condition(s):

deep basin
possibly confined areal extent unkown

Available data:
production well
monitoring wells on site

Notes:

****

Site Name (drainage): 4:8S8W6,7,18,20; 8S9W11,12; 9S8W9
(Beaverhead - Blacktail Deer)

Status: permit application terminated

Potential hydrologic condition(s):
shallow production near stream (Blacktail Deer Creek)

Available data:
about 7 production wells
monitoring wells on site; may need observation wells

Notes:
Seven or more wells TDs ranging from 181 to 330 feet bgs (perforations from 60 to 330)
other wells in the area
previous investigation

****

Site Name (drainage): 5: 9S8W9 (Beaverhead)

Status: permit application in progress(?)

Potential hydrologic condition(s):
shallow near stream (Stoddon Slough, BHR)

Available data:
production well
monitoring well on site (72 hour pumping test)
May need more obs wells

Notes:
existing gw flow model (site)

****

Site Name (drainage):6:1S5W26 (Jefferson), near Waterloo

Status: permit application terminated

Potential hydrologic condition(s):
shallow, near stream

Available data:
production well: 160 feet
monitoring wells on site 1 obs; no assessment

Notes: work done for assessment, but no report presented

****

Site Name (drainage):7: 4S2W35 (Madison) near McAlister, Meadow Creek

Status: permit application terminated

Potential hydrologic condition(s): bedrock aquifer, basin margin

Available data:
production well: 160 feet, perforations 40-160'
monitoring wells on site: 3 observations wells on site,
several wells offsite

Notes:

****

Site Name (drainage):8: 1N4E9 (East Gallatin)

Status: permit application terminated

Potential hydrologic condition(s): basin margin, deep basin - below valley fill, confined(?)

Available data:
production well: 2 wells same depth - 397
monitoring wells on site several, several off site

Notes:
may need observation wells in shallow sediments(?)

****

Site Name (drainage):9:1N4E6 (East Gallatin)
near Manhattan

Status: permit application terminated

Potential hydrologic condition(s): deep basin below valley fill (Tertiary Renova Fm [reported]), valley margin(?)

Available data:
production well: 385 screen at several intervals between 220-387'
monitoring wells on site and off site

Notes:

****

Site Name (drainage):10:6S7W11 (Beaverhead)
Spring Creek, Trout Creek

Status: permit application terminated

Potential hydrologic condition(s): shallow, near stream

Available data:
production well: 613', multiple intervals:193-213,273-293 etc.
monitoring wells on site

Notes:

****

Site Name (drainage):11:6S8W29 (Beaverhead)
Selway Slough
Status: permit application terminated

Potential hydrologic condition(s):
ground water from gravel pit

Available data:
production well: none, gravel pit
monitoring wells on site: none?

Notes:

Appendix 2
Selected Text from HB831

A bill for an act entitled: "an act revising water laws in closed basins; defining terms in water use laws; amending requirements for an application to appropriate ground water in a closed basin; providing that certain applications to appropriate surface water are exempt from closed basin requirements; providing requirements for hydrogeologic assessments, mitigation plans, and aquifer recharge plans; providing minimum water quality standards for certain discharges of effluent; requiring that previously approved plans that were not located in the Clark Fork basin must meet certain criteria; requiring that data be submitted to the Bureau of Mines and Geology; providing for rulemaking; providing for a case study and requirements and a fee for participation in the case study; recognizing and confirming existing appropriation rights in certain instances; providing an appropriation; amending sections 85-2-102, 85-2-302, 85-2-311, 85-2-329, 85-2-330, 85-2-335, 85-2-336, 85-2-337, 85-2-340, 85-2-341, 85-2-342, 85-2-343, 85-2-344, 85-2-402, and 85-2-506, mca; repealing section 85-2-337, mca; directing the amendment of arm 36.12.101 and 36.12.120; and providing an immediate effective date and applicability dates an applicability date."

CLOSED BASINS:
Teton
Upper Clark Fork
Upper Missouri
Madison - Jefferson
Bitterroot

Closed basin case study(Section 23)

(1a) the Montana Bureau of Mines and Geology, provided for in 20-25-211, shall review, assess for scientific accuracy, and compile ground water studies that have been conducted in the last 20 years in closed basins or subbasins in Montana that may have a bearing on better understanding the water balance in these basins with respect to potential ground water withdrawal impacts on surface water.

(1b) after compilation of the information, the Bureau of Mines and Geology shall present recommendations to the appropriate legislative interim committee regarding any additional studies that would help to assess the water balance in closed basins or subbasins with respect to potential ground water withdrawal impacts on surface waters.

(2) the Bureau of Mines and Geology shall conduct a case study to gather and develop data to determine the adequacy of any additional recommended minimum standards and criteria for hydrogeologic assessments, as defined in section 16 15, associated with ground water withdrawals and the range of impacts of those withdrawals on surface water and ground water resources. The Department of Natural Resources and Conservation shall coordinate with the Bureau of Mines and Geology with regard to surface water monitoring and other elements of the case study as necessary.

(3) the case study must be conducted in basins closed pursuant to sections 85-2-330, 85-2-337, 85-2-336, 85-2-341, 85-2-343, or 85-2-344. [*the Teton River Basin (85-2-330, MCA), the Upper Clark Fork River Basin (85-2-336, MCA), the Jefferson River Basin and the Madison River Basin (85-2-341, MCA), the upper Missouri River basin (85-2-343, MCA), and the Bitterroot River sub-basin (85-2-344, MCA).*] The Bureau of Mines and Geology shall ensure that at each site involved in the case study the following, at a minimum, is accomplished to provide the necessary scientific data and information to policymakers:

(a) an appropriate number of monitoring wells are drilled or available to provide scientifically defensible data;

(b) aquifer testing and recovery testing is conducted at the site;

(c) water quality samples are collected from each pumping or primary well at the beginning of the case study and at the end of the case study;

(d) if information or data has already been collected for the site, the information is reviewed, analyzed, and verified by the Bureau of Mines and Geology;

(e) if the site has an established system, that the established system is monitored under its current or planned operating conditions; and

(f) any other information is collected that the Bureau of Mines and Geology determines is necessary to determine recommendations for additional minimum standards and criteria for hydrogeologic assessments, as defined in [section 16 15], associated with ground water withdrawals and the range of impacts those withdrawals have on surface water and ground water resources.

(4) in addition to the requirements of subsection (3), the Bureau of Mines and Geology shall develop a system to compile existing aquifer testing data, as well as data resulting from hydrogeologic assessments, as defined in [section 16 15], and monitoring activities.

(5) the shall coordinate with the Bureau of Mines and Geology to provide surface water measurements to determine impacts, if any, to surface water resources, as appropriate, when a well located at a case study site is pumped.

(6) the Bureau of Mines and Geology shall:

(a) provide updates to the appropriate legislative interim committee throughout the interim related to the progress of the review pursuant to subsection (1) and the case study pursuant to subsections (2) through (5), data trends, if any, and other information necessary to assist the legislative interim committee in developing any necessary policy recommendations;

(b) upon request, provide updates to the ground water assessment steering committee provided for in 2-15-1523; and

(c) submit a report to the appropriate legislative interim committee and the 61st legislature providing a detailed analysis of the results of the review and case study.

Section 24. Case study -- requirements for participation

(1) (a) participants in the case study that are proposing a new ground water appropriation or a change in appropriation right pursuant to 85-2-402(17) are subject to the requirements of sections 15, 14 through 22, 21.

(b) up to a maximum of 10 sites that are the result of a new appropriation or a change in appropriation right may be included in the case study provided for in section 24, 23. If there are more than 10 entities wishing to participate in the case study, the Bureau of Mines and Geology shall select participants to ensure that to the extent possible each closed basin is represented and as many different scenarios are represented as necessary to ensure a scientifically accurate analysis.

(c) if there are fewer than 10 entities wishing to participate or if there is a scenario that is not represented by case study participants that is necessary to ensure a scientifically accurate analysis, the Bureau of Mines and Geology may request cooperation and participation from entities that hold appropriation rights for wells within closed basins.

(d) entities that had an application pending with the on April 11, 2006, must be given the option to participate in the case study before the Bureau accepts other requests for participation.

(2) the Bureau of Mines and Geology, in cooperation with the appropriate legislative interim committee, shall notify each of the entities described in subsection (1)(d), in writing, of the opportunity to participate in the case study and the requirements for participation.

(3) to participate in the case study, a participant shall agree:

(a) that the use of a ground water well in accordance with an application submitted pursuant to section16, 15, 14 does not grant or give the participant an appropriation right;

(b) to allow the installation of monitoring wells and shall allow access for monitoring and review purposes;

(c) if monitoring or test wells exist at the site, to allow the Bureau of Mines and Geology access to those wells for monitoring and review purposes;

(d) to allow for the measurement of pumping at the primary pumping well, including any plumbing requirements necessary to ensure an accurate analysis of pumping records and of the impacts, if any, resulting from pumping of the well; and

(e) that the participant is responsible for costs associated with drilling the primary pumping well, maintenance associated with the well, and other costs reasonably related to the normal operation of a pumping well in the absence of the case study; and

(f) to pay a fee of $15.

BACKGROUND

Introduction to the MBMG

Geology permeates our daily lives to an extent that few of us realize. The very shape of the landscape, the earth resources upon which our society depends, and the health and safety of our communities that may be at risk from geologic hazards are all part of the geologic fabric that surrounds us. Policy decision makers at State and local levels often face conflicting opinions and options regarding competing interests for land, water, mineral, and energy resources. Identification and mitigation of existing and potential geologic hazards, including those that we create and others that are entirely natural, may be surprisingly controversial. Geologic information is critical in resolving these and many other issues.

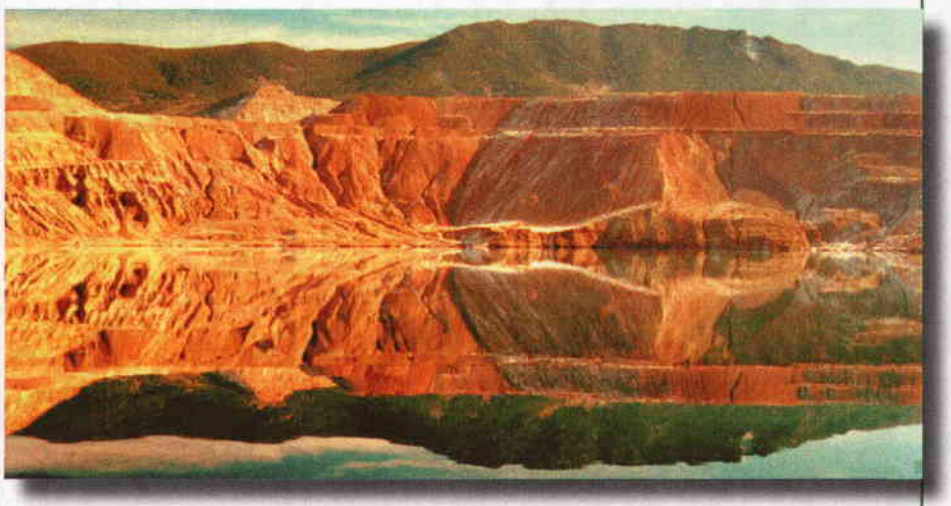
Since 1919, the Montana Bureau of Mines and Geology (MBMG) has been directed by the legislature to address these issues; we are also uniquely qualified to provide integrated answers to these issues. The MBMG is a non-regulatory, applied-research and public-service agency, and the State's geological survey. Our staff scientists have extensive knowledge of ground-water evaluation and protection, superfund sites, resource development and extraction, geologic mapping, and overall expertise in the geology of Montana.

The demand for oil and gas, coal and coalbed methane, cement and lime (limestone), metals, and industrial minerals (talc and garnet) is unprecedented and has fueled Montana's economic growth. As the local economy grows, so does our local demand on those same resources and more—including water. It is easy to see why investigations related to geology, mining, and ground water in Montana are in high demand. In response to that demand, the Montana Bureau of Mines and Geology is actively participating in nearly 100 projects related to minerals and water in virtually every county in the State.

The Montana Bureau of Mines and Geology continues to utilize its grants and contracts program to better serve the needs of Montana citizens and to broaden its overall effectiveness. During the past 2 years, MBMG professionals in Butte and Billings have been involved in 90 outside-funded projects cooperating with 97 different local, State, Federal, and private organizations. These projects, evaluating virtually all aspects of Montana's vast water and mineral resources, are distributed throughout Montana. Many of our projects include students from the Montana University System, providing educational opportunities in earth sciences, engineering, and computer science.

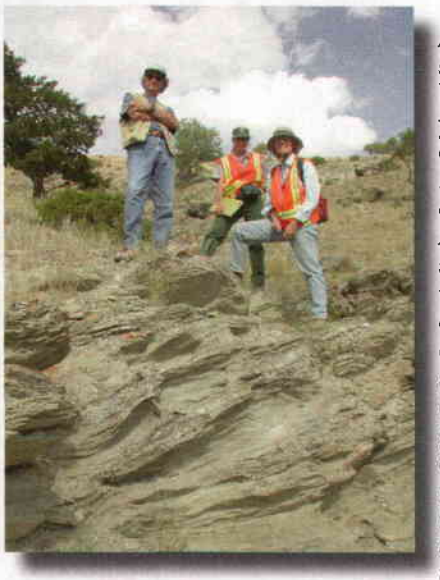
What's New in the 2007 Biennium

*New coal/coalbed-methane geologist
*New statewide geologic map
*New with GWIC: DrillerWeb
*New screening analysis for pharmaceuticals in water
*New ICP instrument provides parts per trillion detection limits and isotope analyses
*New Biennial Report (available now)
*Plans for our new Natural Resources building



The Berkeley Pit. MBMG staff maintain the the Butte Mine Flooding monitoring network, along with Montana Resources and ARCO.

Geology



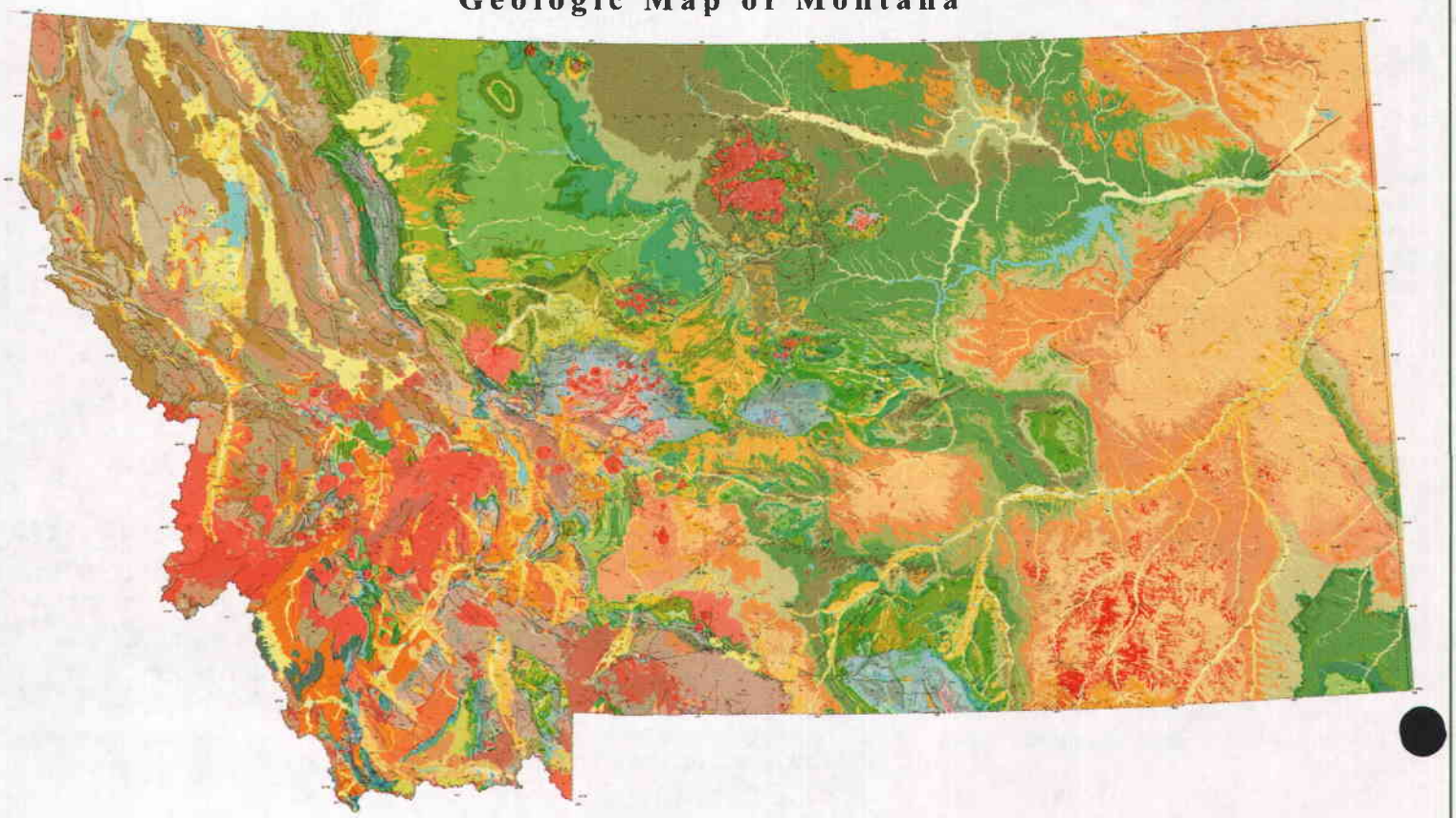
As Montana's geological survey, the MBMG has been engaged for many years in the acquisition of geologic data and the representation of these data on geologic maps. Accurate and appropriately scaled maps are fundamental to addressing virtually every kind of question concerning the earth's surface and subsurface: quantity and quality of ground water, potential for earthquakes, potential for unstable slopes, potential for underground storage of various gases, reserves of commodities like coal and other fossil fuels, extent of mineralization, occurrence of swelling soils, post-fire reclamation, and location and platting of subdivisions, roads, and waste-disposal and power facilities. There is no activity humans engage in on the land surface that cannot benefit from geologic information.

The MBMG's mapping program is supported by State general funds and matching dollars from STATEMAP, a competitive grant component of the National Cooperative Geologic Mapping Program (NCGMP). To date, the MBMG's geologic mapping program has provided digital coverage for 81% of Montana's land surface, represented on 76 integrated geologic maps of several scales and delineating approximately 700 different rock units. These data can be integrated with other types of information, using GIS, to address all land-surface issues. In addition to conducting our own geologic mapping, each year MBMG staff work with several graduate students doing field theses in Montana, funded by the EDMAP component of the NCGMP. The MBMG has responsibility for recommending projects to be funded and for production of the final maps.

A new digital geologic map of the State will be released this spring (a small representation of the map is below). This map will incorporate considerable new geologic information and interpretations that were not available in 1955 when the last map was published, and represents an effort that began more than 10 years ago. The new geologic map will be our springboard for providing the latest geologic mapping information in the coming years.

The MBMG puts great effort into public service, particularly into making our data publicly available. Staff members spend countless hours providing information to individuals or groups, mostly within the State. The traditional methods of information transfer through either our own or external printed publications have been augmented by the astounding growth in delivery of data via the Internet. In the past calendar year, approximately 65,000 copies of publications, mostly geologic maps, were downloaded through the main MBMG website. All of these data were provided at no cost to the user.

Geologic Map of Montana



According to the Montana Natural Resource Information System, ground water provides 94 percent of Montana's rural domestic water supply and 39 percent of the public water supply. The MBMG has over 80 active projects related to surface water and ground water in Montana and focuses on issues critical to water use in agricultural, domestic, fisheries, municipal, and industrial applications.

Water Supply: Quantity and Quality

The demand for abundant, clean ground water grows with the approval of each new subdivision. The MBMG is participating in several projects related to the increasing demand for ground water in new developments and the cumulative impact of septic systems in existing developments. Many areas of Montana have seen a change from agricultural land use to subdivisions and shopping centers. This often means that the irrigated land that was providing recharge to ground water is converted to residential areas with runoff control that actually reduces recharge and adds high demands on ground-water discharge. Such change often has dramatic effects on ground-water flow and quality that are just recently being realized. Of course, the demand for ground water also increases for every year of the drought. Surface-water shortages for agricultural purposes or for drought-stricken communities are being replaced by wells, increasing reliance on the ground-water supply.

Some Current MBMG Water-Resources Projects

*Yellowstone Controlled Ground-Water Area

*Big Hole Watershed Management Project

*Watershed and Ecosystems: A Backyard Classroom

*Salinity Risk Model for the Bullhead Valley

*Helena Valley Ground Water: Pharmaceuticals, Personal Care Products, Endocrine Disruptors, and Microbial Indicators of Fecal Contamination

*Rehabilitating Flowing Wells in the Big Spring Watershed

*Irrigation Potential of Ground Water Underlying the Lower Yellowstone Valley

*Impacts of Oilfield Wastes on Natural Resources

*Improving Soil Productivity and Water Quality in South-Central Montana

*Evaluation of Coalbed-Methane Infiltration Ponds

*Coal Lands Hydrogeology

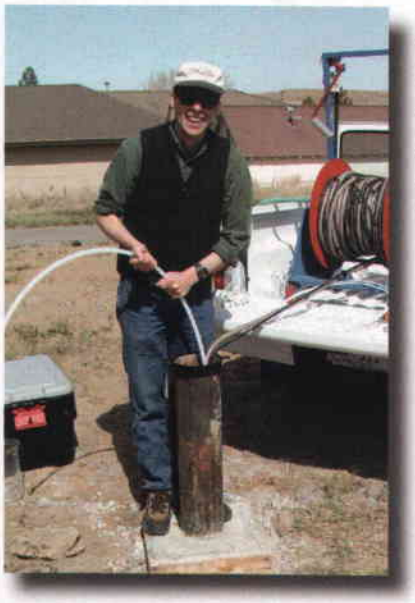
Monitoring Programs

Ground-water flow and quality respond to many influences, both man-made and natural. Several long-term monitoring programs are underway—some for over 30 years now—that provide data for decision makers to address natural and human influences on ground water and geothermal resources, evaluate reclamation in hard-rock and coal mines, and mitigate the effects of the sustained drought. Some of these programs include monitoring of the geothermal area near Yellowstone National Park, the Berkeley Pit and underground workings in Butte, coal strip mines and coalbed-methane fields in southeastern Montana, Big Muddy Creek in the northeast, and post-reclamation monitoring for several hard-rock mines in western Montana.

Special Studies in Ground Water

The MBMG is conducting several investigations related to specific localities or specific issues statewide. Nitrate in ground water has become a challenge for new subdivisions and must be addressed separately for each site. Similarly, pharmaceuticals and other chemicals are finding their way from septic tanks to ground-water supplies. New analytical tools such as isotopes and new analytical instruments for organic chemicals are being employed to develop a better understanding of how ground water can be protected.

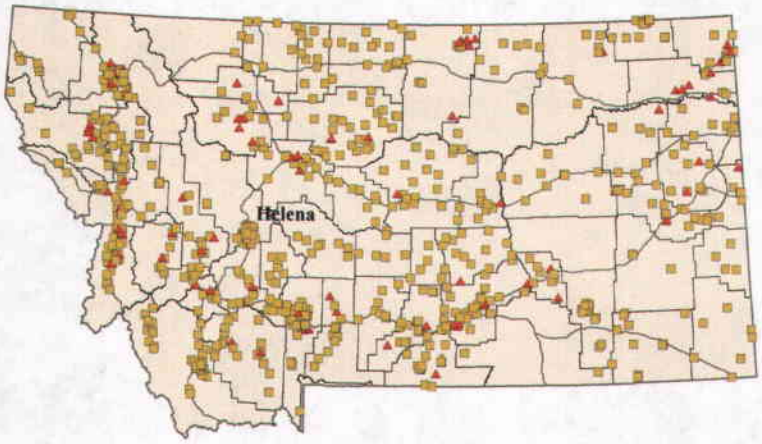
Ground-Water Assessment



The Legislature established the Ground-Water Assessment Program (85-2-901 et seq.) in 1991 after considering the recommendations of a Ground-Water Task Force organized by the Environmental Quality Council. Statute specifically requires systematic **monitoring** and **characterization** of aquifers to improve understanding of Montana's ground-water resources. As part of a mandate to make ground-water information widely available, the Assessment Program includes the **Ground-Water Information Center (GWIC) database** at the Montana Bureau of Mines and Geology. The Legislature also created an interagency Steering Committee that selects study areas, addresses the need for better coordination among State, Federal, and local government units, and oversees Assessment Program progress.

Ground-Water Monitoring

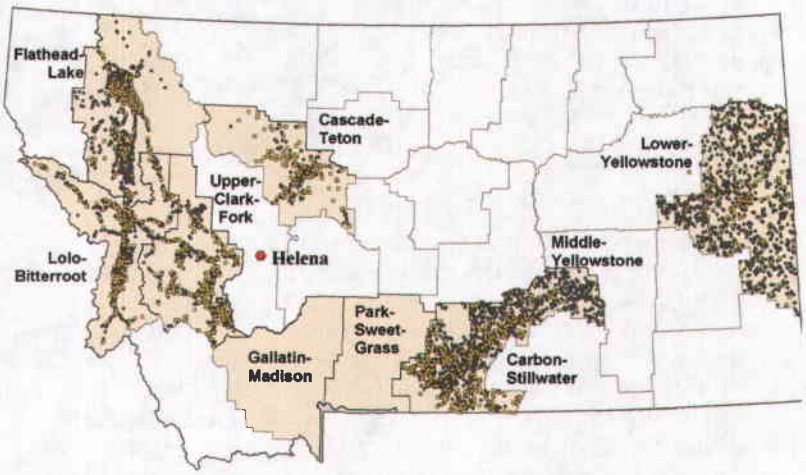
The Ground-Water Monitoring Program measures water levels in 899 strategically located wells each quarter (see map below). Long-term records of water levels in wells are like long-term records of stream flow, and provide information about how ground water responds to seasonal and climatic changes. Water levels in wells also can respond to other factors such as increased withdrawals due to population growth, or from land use change. Without long-term records, these effects are difficult or impossible to distinguish.



Information from the Ground-Water Monitoring Program helps people understand the impact of drought on water levels in wells. Since 2000, about 75 percent of climate-sensitive wells are below their seasonal averages.

Ground-Water Characterization Program

The Characterization Program includes a detailed study of the aquifer system within a specific area. Study areas are prioritized by the Ground-Water Assessment Steering Committee. The locations for more than 6,533 visited wells (dots) and 1,405 samples (yellow squares) collected by Characterization Program staff are shown on the map below.



The Gallatin-Madison and Park-Sweet Grass characterization areas have been selected for future work. Field work is ongoing in the Cascade-Teton characterization area and will begin in the Gallatin-Madison area in spring 2008. The hydrogeology of active/completed characterization areas in 17 counties have been compiled into a series of maps and atlases that cover each area. Since July 2005, 991 maps have been delivered by the GWIC website.

Ground-Water Information Center (GWIC)

GWIC customers seek ground-water data generated by MBMG ground-water-projects, logs from water-well drilling, and results from water-quality sampling.

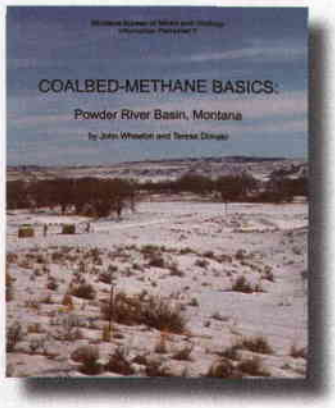
GWIC by the Numbers

*More than 10,700 users
*Currently about 4,900 sessions and 38,000 queries each month
*Information on 204,200 wells
*Results from 32,000 water-quality analyses on 14,350 sites
*1.3 million water-level measurements

On July 1, 2004 drillers began filing well logs directly with the MBMG. The MBMG was also allowed to accept electronic copies of the log. In March 2004 MBMG launched "DrillerWeb," an Internet tool that licensed water-well drillers can use to file water-well logs. DrillerWeb allows a driller to enter and edit data, print well log reports for their customers, manage their well log data in their own "private" account, and at the same time complete their obligation to the state. By November 2006 more than 4,100 logs had been filed through DrillerWeb.

Energy Resources

Coal is an important energy resource for the U.S., with more than half of current electricity produced by coal-fired power plants. Department of Energy data indicate that Montana's recoverable reserve base is the largest of any state. Understanding the quantity, distribution, and quality of these coal reserves is essential for efficient development of this resource. The USGS established the National Coal Resources Data System (NCRDS) as part of their National Coal Resource Assessment Program. The MBMG has collected information on many aspects of coal in Montana for over 20 years; these data are prepared and entered into the NCRDS database. Coalbed methane (CBM) is also a critical resource for Montana.



This free publication, published in 2004, provides basic CBM information for all Montanans.

Underground coal gasification (UCG) is a technology that has been around since World War II; higher petroleum prices and advancement in recovery techniques have renewed interest in UCG here in Montana. The MBMG has responded to several requests from private and government interests regarding potential development. A recent analysis by the MBMG applied such criteria as coal extent, depth, permeability, and quality to identify potential areas of UCG development.

Oil exploration and discovery are also extremely important for Montana's economy. More than 2 billion barrels of oil have been produced from the Big Horn Basin and more than 525 million barrels of oil from the Powder River Basin. The MBMG is actively involved with private industry and with the Crow Tribe in southeastern Montana to develop a new exploration model for the Permo-Pennsylvanian petroleum system; generate maps for industry showing an exploration fairway for oil accumulations in this system; reduce exploration costs by allowing focused exploration in the fairway; and ultimately add petroleum reserves from new discoveries.

Coalbed-Methane Development in Montana

*Began in 1999 with 127 wells producing 8 million cubic feet of methane gas per day

*As of December 2005 there were 516 wells producing 10.5 million Mcf (Mcf = 1,000 cubic feet) per year

*The gas is a high BTU, clean-burning fuel

*Within the Montana portion of the Powder River Basin, 7,500 to 26,000 CBM wells are expected to be drilled in the next 20 years

Mineral Resources

The MBMG has a continuing program of research into mineral commodities that are either being mined or have the potential to be mined in Montana. In recent years the results of investigations on barite, talc, chlorite, vermiculite, and zeolites have been released. Current research is now being focused on metallic districts and gold placers; of particular interest in recent years are sapphire deposits. Known deposits have produced more than 50 tons of sapphires, but the bedrock sources have generally not yet been determined. The MBMG also houses an inventory of maps, mineral property files, and production records on properties; these are primarily metallic minerals but include industrial commodities.

The MBMG's staff mining engineer regularly visits mining and exploration operations across Montana as part of our Small Mine Operators Assistance Program. Technical services typically include operational instruction, feasibility assistance, geologic mapping, surveying, sampling instruction, mine design, reclamation planning, and permitting guidance. Our engineer and geologists answer hundreds of inquiries related to minerals and mining each year.

Mineral Museum

The Mineral Museum has over 1,300 mineral specimens on display and an additional 15,000 specimens in storage. A computerized database facilitates information acquisition on the accessioned collection. Group tours are an important activity of the museum, and during the past biennium about 1,500 individuals in over 80 groups were guided through our displays—over and above our 12,000 individual visitors. In addition to invited speakers and field tours related to mining and minerals, the staff of the museum and the MBMG hold several sessions throughout the year where grade school students are invited to participate in exercises to demonstrate how to find mineral specimens and learn about the many uses of minerals.

Earthquake Studies

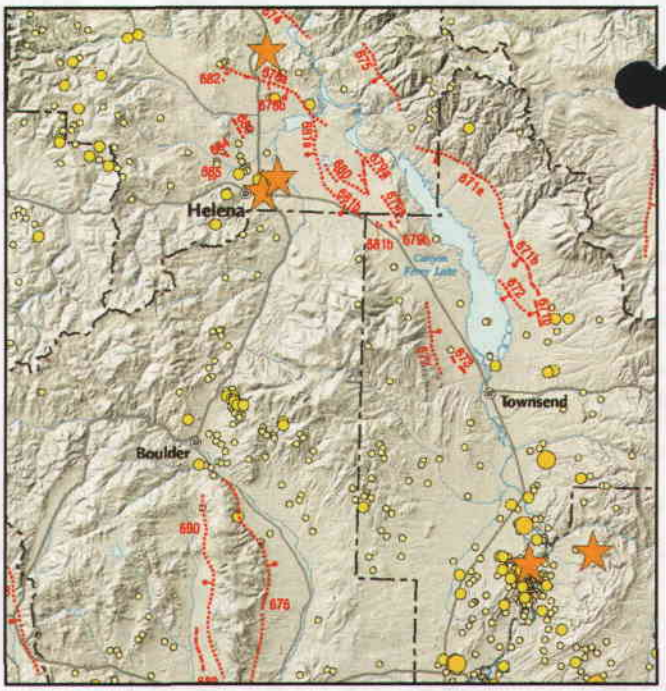
--"We learn geology the morning after the earthquake."
Ralph Waldo Emerson, U.S. Poet, essayist and transcendentalist (1803-1882).

Western Montana has a history of large, damaging earthquakes and remains seismically active.

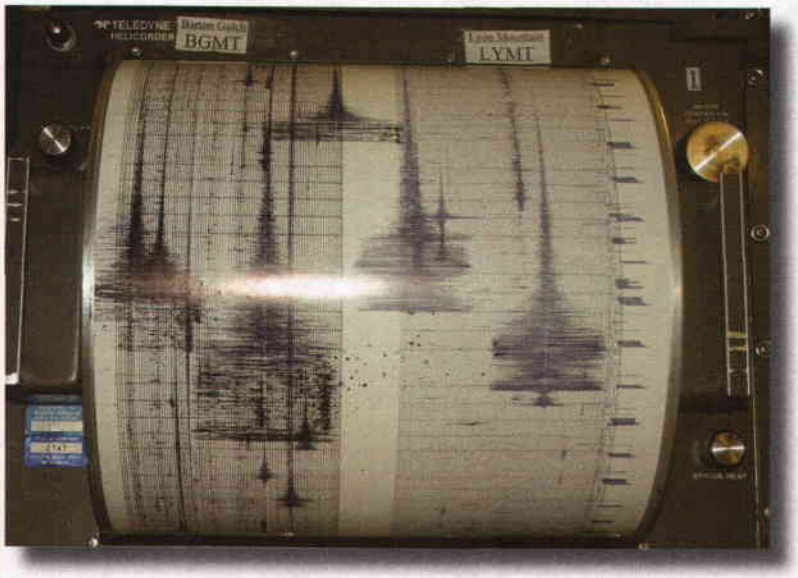
Many of these earthquakes (including the magnitude 6.8 quake north of Three Forks in 1925 and the 1935 magnitude 6.3 and 6.0 quakes that badly damaged Helena) occur at depth along faults that do not extend to the earth's surface. The seismic hazards associated with earthquakes on these "blind" faults cannot be evaluated with traditional geologic studies of faults and are best studied with data from a permanent network of seismograph stations. As the population and infrastructure of earthquake-prone western Montana continues to grow, the exposure to seismic hazards increases.

A network consisting of 38 seismic monitoring stations operates throughout western Montana, the most seismically active region of the State. Four additional stations operate in less seismically active eastern Montana. Other regional seismic monitoring centers provide additional seismic data from stations in the surrounding region (Yellowstone Park, central Idaho, and southern Canada).

The MBMG records a total of 171 channels of seismic data from 82 local and regional stations; improvements in the system enable near-real-time reporting of significant events to the National Earthquake Center, where they are used by appropriate State and Federal agencies (Montana Disaster and Emergency Services, Montana Dam Safety Program, CSKT Dam Safety Program, and USGS), the public, and the media. Using the data from this extensive seismograph network, the times, locations, and magnitudes of earthquakes are determined and catalogued.



A portion of MBMG Special Publication 114 showing known potentially active faults in the Helena region along with selected earthquake epicenters.



Seismograph record of the July 2005 5.6-magnitude earthquake centered in Dillon.

A listing of recent earthquakes, along with other information about seismic hazards in Montana, is available on the MBMG Earthquake Studies Office website (http://mbmgquake.mtech.edu/).

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EDUCATION

2000 Ph.D., Michigan State University (Geological Sciences), Dissertation: Chromium Speciation and Mobility in Contaminated Soils, Sault Ste. Marie, MI.

1993 M.S., University of Nevada, Las Vegas (Geosciences), Thesis: Evaluation of a filter pack dewatering on VOC concentrations in a simulated low-yield monitoring well.

1990 B.S., University of Montana (Geology), Thesis: Geology in the Northwest Part of the Potomac Valley, Montana.

RELEVANT EXPERIENCE

2006-Present	Associate Research Professor, Montana Bureau of Mines and Geology (MBMG)
2005-2006	Assistant Research Hydrologist, MBMG
2003-2005	Post-Doctoral Research Associate, Chemistry Division, Los Alamos National Laboratory.
2000-2003	Post-Doctoral Research Associate, Department of Geological Sciences, Pennsylvania State University.
1996-1998 and 1999-2000	Graduate Research Assistant, Department of Geological Sciences, Michigan State University.
1993-1994	Staff Hydrogeologist, Water Resources Center, Desert Research Institute, Las Vegas, Nevada.
1990-1993	Graduate Research Assistant, Water Resources Center, Desert Research Institute, Las Vegas, Nevada.

PUBLICATIONS

Icopini, G.A., Boukhalfa, H., Reilly S.D., and Neu, M.P., (in preparation), Pu(V)/(VI) Reduction by Metal Reducing Bacteria, In preparation for *Environmental Science and Technology.*

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Icopini* G.A., S.L. Brantley, S. Ruebush, M. Tien, and T.D. Bullen, 2002, Iron Fractionation During Microbial Reduction of Iron, *Eos Trans. AGU, 83*(47), Fall Meet. Suppl., Abstract B11A-0706.

RESEARCH ACTIVITIES (2000-2007)

- Investigated Cr geochemistry of in contaminated areas
- Investigated role of metal-reducing bacteria in the fate and transport of metals in subsurface environments
- Assessed and modeled silica solubility in simulated hydrothermal systems
- Investigated the effect of actinide contamination on the microbial ecology of soils
- Assessing the distribution of endocrine disrupting chemicals in Montana; NRCS

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EDUCATION

1987 M.A., University of Texas, Austin, Texas (Geology)
1983 B.S., University of Wisconsin, Madison, Wisconsin (Geology)

RELEVANT EXPERIENCE

2002 – present: Montana Bureau of Mines and Geology: Associate Research Hydrogeologist
1993 – 2002: Montana Bureau of Mines and Geology: Assistant Research Hydrogeologist
1992 - 1993: Leggette, Brashears & Graham, Inc., St. Paul, MN: Associate Hydrogeologist
1990 - 1992: Leggette, Brashears & Graham, Inc., St. Paul, MN: Senior Hydrogeologist
1987 - 1990: Leggette, Brashears & Graham, Inc., St. Paul, MN: Hydrogeologist

RESEARCH ACTIVITIES

- Ground-Water Resource Evaluation
- Ground-Water Geochemistry
- Isotope Hydrology
- Ground-Water Age Dating

PUBLICATIONS (1999 - present only)

LaFave, J.I., 2006, Potentiometric surface of the basin-fill and bedrock aquifers, Mineral and Missoula counties, Montana (open-file version), Montana Bureau of Mines and Geology: Ground-water Assessment Atlas 4B-06, 1 sheet(s), 1:100,000.

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EDUCATION

2004 Ph.D., University of Montana (Geology), Dissertation: Geochemical evolution of flooding mine waters in a zoned, sulfide-hosted ore deposit, Summit Valley Mining district, Butte, Montana
1990 M.S., Montana College of Mineral Science and Technology (Geological Engineering)
1986 B.S., Montana State University (Earth Science - Geology)

RELEVANT EXPERIENCE

1989 - 1990 Hydrogeologist, Montana Bureau of Mines and Geology

1990-1995:Assistant Research Hydrogeologist

1995-2003: Associate Research Hydrogeologist

2003-present: Senior Research Hydro geologist

2004-present: Research Division Chief

PUBLICATIONS (1997-present)

Metesh, J.J. and Duame, T.E., 1997, Abandoned-inactive mines in Montana - 1996, 1:750,000-scale map, MBMG Special Publication 111, January 1997.

Metesh, J.J., Lonn, Marvin, R.K, Hargrave, P.A., and Madison, J.P., 1998, Abandoned-inactive mines in the Helena National Forest, Volume I: Upper Missouri River Drainage, May 1998, Montana Bureau of Mines and Geology Open-file Report 352, 195 pages.

Hargrave, P.A., Bowler, T.P., Lonn, J., Madison, J.P, Metesh, J.J., and, Wintergerst, R.,1998, Abandoned-inactive mines in the Helena National Forest, Volume II: Blackfoot and Little Blackfoot River Drainages, February,1998, MBMG Open file report 368, 181 pages.

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RESEARCH ACTIVITIES (2000-2006)

- Hydrogeology and geochemistry related abandoned-inactive mines on USFS and BLM lands; USDA and USDOI.
- Hydrogeology and geochemistry related to the Butte Area Superfund Site; MDEQ.
- Modeling the effects of water-level rise on the adjacent alluvial aquifer, Berkeley Pit, Butte, MT; EPA-DOE
- Modeling drawdown related to coal-bed methane development in southeastern Montana; USDOI
- Modeling return flows from irrigation in the upper Big Hole River basin; DNRC
- Large-scale modeling of the product recovery system at the Montana Pole site, Butte, Montana; MDEQ

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EDUCATION

1987 M.S., Montana College of Mineral Science and Technology, Geology
1973 B.A., Valparaiso University, Geography/Geology

RELEVANT EXPERIENCE

1974-1978: Geohydrologist, Montana Department of Natural Resources and Conservation.
1978-2002: Hydrogeologist, Assistant Research Hydrogeologist, Associate Research Hydrogeologist, Sr. Research Hydrogeologist, Montana Bureau of Mines and Geology.
1997-2007: Program Manager: Montana Ground-Water Assessment Program Montana Bureau of Mines and Geology.

PUBLICATIONS (1997-present only)

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RESEARCH ACTIVITIES (2000-2007)

- Climate forcing as reflected in long-term ground-water-level monitoring records.
- Evaluation and development of data structures in the Ground-Water Information Center to house aquifer test data.
- Development of ground-water data storage and distribution processes to more efficiently distribute data held by the Ground-Water Information Center.

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EDUCATION

1988 M.S., Wright State University, Dayton OH (Geology-Hydrogeology) Thesis: Fracture Controlled Erosional Processes and Groundwater Flow in the Niagara Group Carbonates, Southwestern Ohio
1985 B.A., University of Montana (Geology)

RELEVANT EXPERIENCE

1988 – 1989: Hydrogeologist, Rittenhouse-Zeman and Associates, Bellevue, Washington
1989 – 2000: Hydrogeologist, Water Management Bureau, Montana Department of Natural Resources and Conservation
2000 – 2006: Hydrogeologist and Reclamation Specialist, Industrial and Energy Minerals Bureau, Montana Department of Environmental Quality

PUBLICATIONS

Roberts, M. and Waren, K., 2001; North Fork Blackfoot River Hydrologic Study, Montana Department of Natural Resources and Conservation DNRC Report WR-3.C.2.NFB.

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RESEARCH ACTIVITIES (2000-2006)

- Hydrogeology and geochemistry related to the Colstrip Coal Deposit; MDEQ.
- Evaluating the effects of mining and dewatering at the Bull Mountains Mine, MDEQ
- Evaluating ground water monitoring plans for the Circle GNP power plant project, MDEQ